

THE FUTURE OF
WAR ★

DRONES AND REALLY BIG GUNS

THE GEEK'S GUIDE TO
SUMMER MOVIES

★ WHY WE ♥
PLUTO

(BY THE MAN WHO KILLED IT)

JULY 2015

POPULAR SCIENCE

THE *RACE* TO BUILD THE **HYPERLOOP**

IS ELON MUSK'S NEXT BIG IDEA
REAL—OR RIDICULOUS?

760 MPH
COMMUTE!
SAN FRANCISCO TO L.A. IN
30 MINUTES!

PLUS!

4-D FUTURE • A CAR TO END ACCIDENTS
KILLER SATELLITES • HOW TO SEE PAIN

"Tube-vehicle systems are potentially the fastest of all ground systems, and we are studying several concepts."

—John A. Volpe, U.S. Secretary of Transportation, *Popular Science*, December 1969

Saving People Money Since 1936

**... that's before the sound
barrier was broken.**

GEICO has been serving up great car insurance and fantastic customer service for more than 75 years. Get a quote and see how much you could save today.

geico.com | 1-800-947-AUTO | local office

GEICO®



Some discounts, coverages, payment plans and features are not available in all states or all GEICO companies. GEICO is a registered service mark of Government Employees Insurance Company, Washington, D.C. 20076; a Berkshire Hathaway Inc. subsidiary. © 2015 GEICO



Featuring

HYPED UP

A near-supersonic commute might arrive sooner than you think. Startups are racing to bring the hyperloop to life. **JAMES VLAHOS** [PAGE 32](#)

WEIRD SCIENCE

This summer's sci-fi blockbusters are so bizarre, they must be fiction. Right? We asked the experts. **ERIK SOFGE** [PAGE 40](#)

A HACKER'S GUIDE TO SMART YARDS

Tired of mowing the lawn? Learn how to build a more efficient, automated home from the outside in. **CORINNE IOZZIO** [PAGE 52](#)

WHY I STILL LOVE PLUTO

The first close-ups of the dwarf planet will mark the end of an era—and the beginning of a new one. **MIKE BROWN** [PAGE 56](#)

FUTURE OF WAR

The risk of conflicts between great powers is rising. How will that change the battlefield of tomorrow? **P.W. SINGER**

Departments

FEED

- [06](#) From the Editor
- [08](#) A Bit About Us
- [10](#) Peer Review

NOW

- [13](#) A projector for screening movies anywhere
- [14](#) Ten things we love this month
- [16](#) A car to end all accidents
- [17](#) Say goodbye to slow Wi-Fi
- [18](#) The founder of Slack on the future of communication
- [20](#) Advanced armor for road warriors

NEXT

- [23](#) Peek inside Earth's mantle
- [24](#) Our 4-D future will assemble itself
- [26](#) A wind machine you can live in
- [28](#) Technology that lets doctors see pain
- [30](#) Temple Grandin on how to raise resilient animals
- [31](#) Mosquitoes designed to die

MANUAL

- [61](#) This flashlight runs on dead batteries
- [64](#) Wearable tech straight from the '70s
- [65](#) A tool for making perfect wood cuts
- [66](#) How to blow smoke rings without inhaling
- [67](#) A skateboard you can fold in half

END MATTER

- [68](#) Ask Us Anything: Does sugar make kids hyper?
- [78](#) From the Archives

ON THE COVER

Our vision of the 760 mph hyperloop. Illustration by Tavis Coburn.

Dare to Dream Big

Anyone familiar with *Popular Science* probably recalls our vintage covers. Back in the 1920s, '30s, and '40s, we developed a signature style that depicted, in hand-painted detail, extraordinary machines of the future. We showed transcontinental airships, 50 mph ice-cycles, floating tractors, and any number of

improbable vehicles that appeared to defy the laws of physics (most did).

Some of the covers were true works of art—check out May 1946, one of my favorites—while others were downright bizarre: July 1937 featured a tanklike thing rumbling out of a swamp and heading straight for a tiger. A tiger! What unified the covers was their unabashed enthusiasm for the future. They made clear that *Popular Science* embraced technology and its ability to bring a brighter day, no matter

how distant that day might be. Nearly a century later, that wide-eyed optimism still drives us here at the magazine. It colors our smallest stories and our biggest features. And, of course, it still influences our covers, albeit in a very different way. Once in a while, though, we find something so audacious and visionary that we're compelled to bring back our retro style. That's the case with the hyperloop.

You've heard of it. In 2013, Elon Musk, the man behind SpaceX and

OUR VINTAGE
COVERS MADE CLEAR
THAT *POPULAR*
SCIENCE EMBRACED
TECHNOLOGY AND ITS
ABILITY TO BRING A
BRIGHTER DAY.



Tesla, tossed out a concept for a 760 mph low-pressure train system. The world speculated madly for about a week—San Francisco to Los Angeles in less than an hour! Then as quickly as it arrived, the idea of the hyperloop seemed to disappear.

Only it didn't. Two startups have been beaver away on it since. They have recruited employees and volunteers, and have worked up prototype designs. One of them, Hyperloop Transportation Technologies, has announced its intention to build a test track in California next year. Even Musk picked the idea back up. In January, he tweeted that he wanted to build a hyperloop pilot project, most likely in Texas.

Can these companies reinvent transportation in one stroke? We explore that question in "Hyped Up"

(page 32), but I'll give you my take: I certainly hope so, but the challenges are legion. And in some ways, I think it doesn't really matter. The hyperloop has captured popular imagination as few ideas do. At this point, it doesn't just represent a new mode of transportation. It represents the promise of a better life. It's a window into what could be, if only we apply some elbow grease.

As a nation, and as a planet, we need more of that spirit—the inspiration to dream big—and in that regard, the hyperloop has succeeded already.

Enjoy the magazine.

Cliff Ransom
Editor in Chief

Contributors



Peter W. Singer

Defense analyst Peter W. Singer doesn't think World War III is inevitable, but that we should prepare for it. "The risk of the brewing Cold War with Russia and China turning hot is one we have to take seriously," he says, "especially to avoid it." Drawing from his book *Ghost Fleet: A Novel of the Next World War*, he assesses the world's sea, land, air, and cyber arsenals in "The Future of War" (page 46).



Judy Foreman

A few years ago, health writer Judy Foreman began feeling severe neck pain. "On a scale of 1 to 10," she says, "it was a 20." Prior to that, she believed chronic-pain sufferers were exaggerating. "No more," says Foreman, who tackled the topic in her book, *A Nation in Pain—Healing Our Biggest Health Problem*. In "We See Your Pain" (page 28), she writes about a new imaging technique for chronic sufferers.



Tavis Coburn

When illustrating our hyperloop cover this month, artist Tavis Coburn turned to the *Popular Science* archive. "The magazine, from the '40s to the '70s, has been a huge inspiration for me," he says. Coburn's image nods to both past and future. "I feel ripped off that we are not flying in cars and teleporting around," he says. "The hyperloop is a vision of the future we really should be living in."



Mike Brown

As the man who "killed" Pluto, Mike Brown doesn't regret the reclassification of everyone's favorite planet. "The killing was fun," he says, "because it was really about discovering new objects at the edge of the solar system and learning how it formed." In "Why I Still Love Pluto" (page 56), the planetary astronomer at the California Institute of Technology explains what the former planet can teach us next.

SIGMA

THE GO-GETTER.

A compact, lightweight hyper-telephoto zoom lens featuring outstanding optical performance and optimal portability.

The latest fine lens in our Contemporary line.

C Contemporary

150-600mm F5-6.3 DG OS HSM

Case, hood (LH1050-01) included.
USA 4-Year Service Protection



SIGMA USB Dock

Update, adjust & personalize. Customization never thought possible. Sold separately.





A Bit About Us

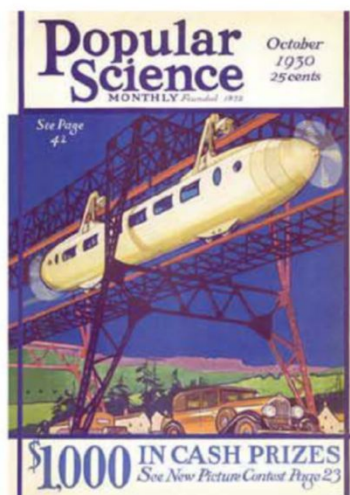


THE VIZZIES

The most beautiful visualizations from the worlds of science and engineering

Do you love animating data, creating science apps, or taking macrophotographs? In the 2015 Visualization Challenge, sponsored by *Popular Science* and the National Science Foundation, your handiwork can receive its due glory.

Enter at nsf.gov/news/vizzies through Sept. 15.



HOW HISTORY HELPS US VIEW THE FUTURE

It doesn't hurt to have an archive filled with 143 years of science and technology. It was precisely that history that inspired this month's cover featuring the hyperloop. This cover from October 1930 wowed readers with an early monorail concept.

Q: WHAT SCI-FI LOCALE DO YOU WANT TO VISIT THIS SUMMER?

1 Tatooine. I've always wanted to see that double sunset, and I hear Tosche Station is hopping this time of year.

2 The planet Uriel from *A Wrinkle in Time*, so I can visit the Mrs Ws

3 Narnia! Mr. Tumnus was a hybrid man-goat species; that makes it sci-fi, right?

4 The new Area 51—Dugway Proving Grounds outside Salt Lake City

5 I wish Jurassic Park were real and not fatally dysfunctional. A smoothly run Jurassic Park. One can dream.

6 Considering I hate the summer heat, I'd go to Jotunheim from *Thor* (where the frost giants live).

7 Milliways, the Restaurant at the End of the Universe

TEST SUBJECTS

In the midst of producing this issue, our office hosted Take Your Child to Work Day. Lucky for us, that meant we had plenty of (tiny) helping hands to test the make-your-own smoke rings project on page 66.



For reprints, email: reprints@bonniercorp.com.

FOR CUSTOMER SERVICE AND SUBSCRIPTION QUESTIONS, such as renewals, address changes, email preferences, billing, and account status, go to popsci.com/cs. You can also call 800-289-9399 or 515-237-3697, or write to *Popular Science*, P.O. Box 6364, Harlan, IA 51593-1864.

Follow us on twitter @popsci

EDITOR IN CHIEF Cliff Ransom
Design Director Todd Detwiler
Executive Editor Jennifer Bogo

EDITORIAL

Managing Editor Jill C. Shomer
Editorial Production Manager Felicia Pardo
Articles Editor Kevin Gray
Information Editor Katie Peek, Ph.D. **1**
Technology Editor Michael Nuñez
Projects Editor Sophie Bushwick **2**
Associate Editors Breanna Draxler, Lois Parsley, Jen Schwartz
Assistant Editor Lindsey Kratochwill **3**
Editorial Assistant Grennan Milliken
Copy Editor Cindy Martin **4**
Researchers Ambrose Martos, Shannon Palus, Erika Villani
Editorial Intern Rachel Fobar **5**

ART AND PHOTOGRAPHY

Photo Director Thomas Payne
Digital Associate Art Director Michael Moreno
Designer Zachary Gilyard **6**

POPULARSCIENCE.COM

Online Director Carl Franzen
Senior Editor Paul Adams
Assistant Editors Sarah Fecht, Loren Grush
Producer Joey Stern
Contributing Writers Kelsey D. Atherton, Mary Beth Griggs, Alexandra Ossola **7**

CONTRIBUTING EDITORS

Brooke Borel, Tom Clynes, Matthew de Paula, Clay Dillow, Nicole Dyer, Daniel Engber, Tom Foster, Hackett, Mike Haney, Joseph Hooper, Corinne Iozzio, Gregory Mone, Adam Pioré, P.W. Singer, Erik Sofge, Kalee Thompson, James Vlahos, Jacob Ward

BONNIER TECHNOLOGY GROUP

Group Editorial Director Anthony Licata
Group Publisher Gregory D. Gatto
Chief Marketing Officer Elizabeth Burnham Murphy
Financial Director Tara Biscicello
Eastern Sales Director Jeff Timm
Northeast Advertising Office Margaret Kalaher, Matt Levy, Amanda Smyth
Midwest Managers Carl Benson, Doug Leipprandt
Ad Assistant Lindsay Kuhlmann
West Coast Account Managers Stacey Lakind, Sara Laird O'Shaughnessy
Detroit Advertising Director Jeff Roberge
Detroit Manager Ed Bartley
Direct Response Sales Shawn Lindeman, Frank McCaffrey, Chip Parham
Digital Campaign Managers Amanda Alimo
Digital Campaign Coordinator Justin Ziccardi
Group Sales Development Director Alex Garcia
Senior Sales Development Manager Amanda Gastelum
Sales Development Managers Kate Gregory, Charlotte Grima
Creative Services Director Ingrid M. Reslmaier
Marketing Design Directors Jonathan Berger, Gabe Ramirez
Marketing Design Manager Sarah Hughes
Digital Design Manager Steve Gianaca
Group Events & Promotion Director Beth Hetrick
Promotions Managers Eshonda Caraway-Evans, Lynsey White
Consumer Marketing Director Bob Cohn
Public Relations Manager Molly Battles
Human Resources Director Kim Putman
Production Manager Erika Hernandez
Corporate Production Director Jeff Cassell
Group Production Director Laurel Kurnides

BONNIER

Chairman Tomas Franzén
Chief Executive Officer Dave Freygang
Executive Vice President Eric Zinczenko
Chief Content Officer David Ritchie
Chief Financial Officer Todd DeBoer
Chief Operating Officer Lisa Earlywine
Chief Marketing Officer Elizabeth Burnham Murphy
Chief Digital Revenue Officer Sean Holzman
Vice President, Integrated Sales John Graney
Vice President, Consumer Marketing John Reese
Vice President, Digital Audience Development Jennifer Anderson
Vice President, Digital Operations David Butler
Vice President, Public Relations Perri Dorset
General Counsel Jeremy Thompson



This product is from sustainably managed forests and controlled sources.

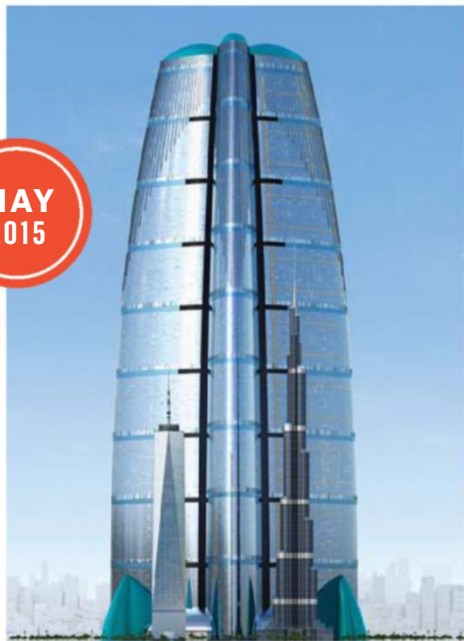


MADE IN OUR
IMAGE
OUT OF OUR
CONTROL

H U M A N S

NEW SERIES PREMIERE
SUN JUNE 28TH 9/8C

amc

MAY
2015

KEEP IT ON THE DOWN-LOW

I am very much in favor of faster, more-efficient elevators ["An Elevator That Will Reshape Skyscrapers"]. But that does not mean we should build even taller structures. There are many reasons not to go higher: fire fighting, evacuation, natural disasters, and eventual demolition immediately come to mind. Just because we can do something doesn't mean we should.

John Corcoran, Clifton, VA

DRONE OVERDOSE

I appreciate all that you guys do to keep the average individual informed. But I don't think I'll be the first to say: Enough with drones!

John Froese

We apologize... On page 40 of the May issue, the battery capacity of the C-1 should have been listed in kilowatt-hours. And on page 70, the diode referenced was one of the germanium variety, rather than geranium. Flowers don't make for great circuits.

TWEET OUT OF CONTEXT

Thanks, now I feel better about the fact that I've been too lazy to walk across my own continent to throw something into a volcano.
@theurbansherpa

BIOACCUMULATION ISSUES ASIDE...

The article on entomophagy ["The Rise of the Incredible, Edible Insect," May 2015] got me wondering how this environmentally friendly trend could be improved even more. Are there any bugs that could feed off landfills? Then we'd be killing two birds with one stone: reducing our waste by harvesting more food for ourselves.

Ben Sandeen, Evanston, IL

ALMOST FAMOUS

I wanted to send a quick thank-you to the entire team for one of the most

incredible moments of my life! Humbled and grateful,

Katarzyna "Kasia" Sawicka

[Featured inventor in the 2015 "Invention Awards," May]



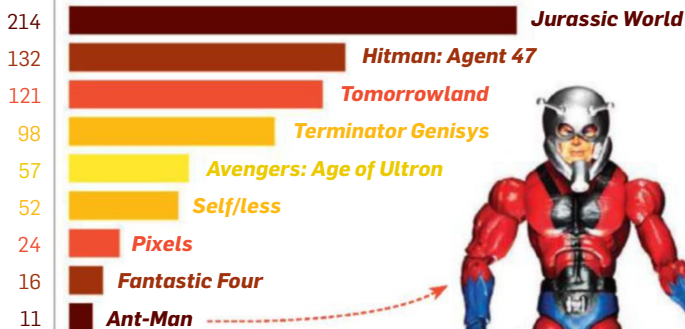
HAVE A COMMENT?

Write to us at letters@popsci.com or to PopSci@popsci.com
2 Park Ave., 9th floor
New York, NY 10016

SCIENCE-FICTION SHOWDOWN

Which summer sci-fi flick do PopSci readers think is most true to science?

Votes



To find out how close the movies actually get, check out "Weird Science" on page 40.

Show & Tell

On page 52, we explain how to hack your yard. But there are plenty of backyard tinkerers already out there. Send us a photo or description of the smartest upgrades you've seen on a neighbor's lawn—or your own.

**Get the wireless plan
that Money Magazine
named the "BEST."**

**Or get some
other plan.**

Your call.

**Straight
Talk[®]**
wireless

**Get the Unlimited* plan named Best Individual
Plan for Typical Users by MONEY® Magazine.**

Get 4G LTE coverage on America's largest and most dependable networks for up to half the cost†. Unlimited talk and text with 3GB of high-speed data is just \$45 a month with no contract. Start saving at StraightTalkSwitch.com

Only at
Walmart 

From MONEY® Magazine, July 2014 ©2014 Time Inc. Used under license. MONEY Magazine and Time Inc. are not affiliated with, and do not endorse products or services of, Licensee. LTE is a trademark of ETSI.

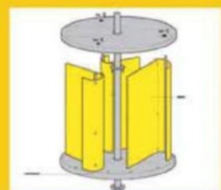
*30-day Unlimited Plans include 3GB of high-speed data per 30-day cycle. After 3GB, your data speed will be reduced to as low as 64kbps for the remainder of the 30-day cycle. If your data speed is reduced, the reduced speed may impact the functionality of some data applications, such as streaming audio or video or web browsing. Straight Talk reserves the right to terminate your service for unauthorized or abnormal usage. Please refer always to the latest Terms and Conditions of Service at StraightTalk.com.

†"Half the Cost" is based on a service comparison of the two largest contract carriers' monthly online prices for comparable individual post-paid contract service plans and Straight Talk's \$45 service plan. Excluding the cost of the phone, additional fees and limited time promotions. Source: Contract carriers' websites, March 2015.

MAKE YOUR MARK!

Master 200+ Must-Know
DIY Tips and Tricks

Popular Science delivers the step-by-step instructions and game-changing insights you need to transform a back-of-the-envelope idea into a gleaming finished product.



Generate power with a
DIY wind turbine!



Cast a shot glass in a
brick!

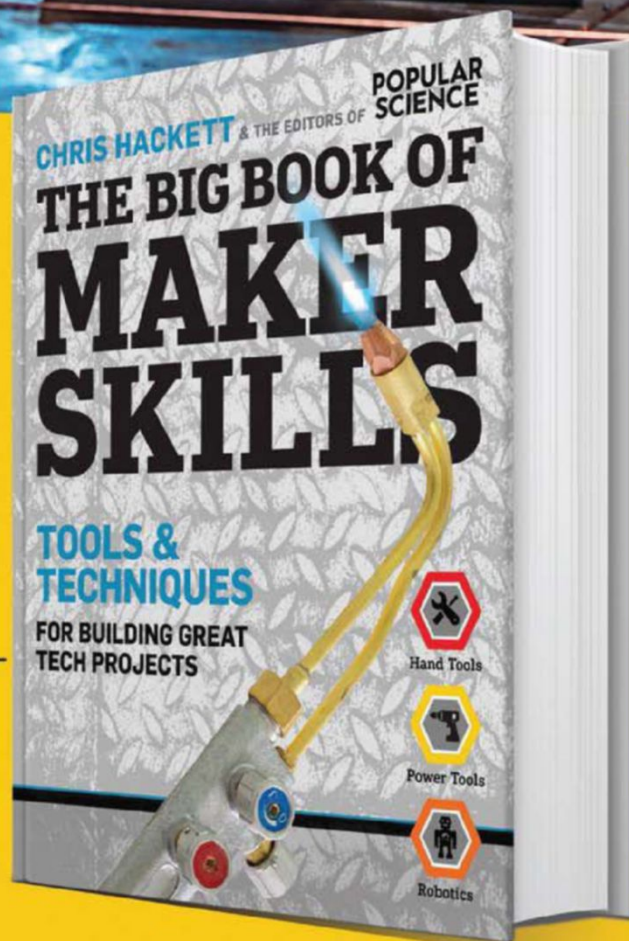


Build your first 'bot,
from scratch.

Order your copy and
FREE LED FLASHLIGHT at



POPSCI.COM/MAKERBOOK



EDITED BY **Michael Nuñez & Lindsey Kratochwill**



SPECS

Projection

size 14 to 120 inches

Resolution 720p

Bulb life 20,000 to 50,000 hours

Battery life

2.5 hours streaming

Ports HDMI, USB

Price \$399 on contract

THE PERFECT PROJECTOR FOR STREAMING



Setting up a backyard movie screening sounds like a great idea—until you try it. You need an outlet or extension cord, and even more cables to connect a computer or streaming box to your projector. The ZTE Spro 2 frees you from that. An update to last year's original Spro, the portable projector has a 200-lumen bulb—double that of its predecessor. A full Android operating system makes it an all-in-one device with touchscreen navigation to load the latest movie

and project it up to 120 inches.

There's no need to worry about spotty Wi-Fi slowing down streaming because Spro 2 creates its own hotspot for up to 10 devices using 4G LTE or a wireless network. What's more: It can connect wirelessly to your computer or streaming box

thanks to Bluetooth, or serve up videos straight from its 16GB hard drive or apps available from the Google Play store. To get the full cinema experience, add your favorite wireless speaker and enjoy your own backyard theater under the stars.

RACHEL FOBAR





Obsessed

Some things are just...better

LINDSEY KRATOCHWILL

1 VAPOURLIGHT HYPER SMOCK 2.0

On long hiking trips, every ounce matters, so Berghaus has created the lightest-weight waterproof jacket yet. At a mere 85 grams for a size large, it's roughly 30 percent lighter than its nearest competitor. **\$150**

2 TRAINER BY GIBSON

Legendary guitar maker Gibson worked with Olympian Usain Bolt to develop wireless over-ear headphones for runners. Built-in LEDs in the earpieces increase nighttime visibility. At the touch of a button, you can also lower the volume to stay alert during your run. **\$250**

3 STOWER CANDLECHARGER

With Stower's Candle Charger system, a single Sterno canister can charge a smartphone—twice. The candle's flame heats and purifies a pot of water, which serves as a thermoelectric generator. **\$99**

4 MISFIT SWAROVSKI SHINE

Who says you can't count steps at a black-tie event? Misfit's newest activity tracker comes with a Swarovski crystal face and can be worn with nine different accessories, so it will fit in with your wardrobe whether you're at the gym or next year's Met Gala. **From \$169**

5 BIG SCIENCE

Pulitzer Prize-winning writer

Michael Hiltzik tells the tale of a Nobel Prize winner: Ernest Lawrence, who created the Cyclotron. *Big Science* chronicles how Lawrence's early particle collider helped to revolutionize nuclear physics. **\$30**

6 MILWAUKEE M18 JOBSITE FAN

Milwaukee's new jobsite fan moves air at 284 cubic feet per minute and can run on battery power for up to 17 hours—enough time to dry wet paint and plaster on the job. It can also swivel 120 degrees, so you don't need to constantly reposition it. **\$79**

7 TOMTOM BANDIT ACTION CAMERA

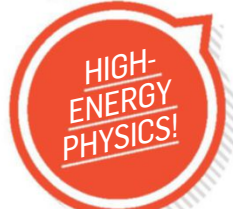
TomTom's Bandit lets you edit on the go—no need to download footage onto a computer. Motion and GPS sensors tag your most extreme moments, and a companion smartphone app turns them into a highlight reel. **\$399**

8 COLOR ALIVE

Crayola's new app can capture coloring-book masterpieces and turn them into animated 3-D figures. Kids can play with their creations in the app, and even take selfies with them. **Free**

9 POPSLATE

Snapping this case onto an iPhone 6 adds a 4-inch shatterproof ePaper screen to the back of the device. The popSLATE can last for seven days on a single charge. **\$129**



10 GEEKS WHO DRINK

Syfy's latest show is like a trip to the bar on trivia night—except you get to watch from your couch. Hosted by Zachary Levi, hero of the spy comedy *Chuck*, the weekly game show grills geeks on topics like pop culture and science fiction. Pick up a few pieces of awesomely nerdy knowledge to impress your friends the next time you're making conversation at a cocktail party. **July 16**



FROM TOP LEFT: COURTESY BERGHAUS; COURTESY MILWAUKEE TOOL; COURTESY POPSLATE; COURTESY NBCUNIVERSAL; COURTESY TOMTOM; COURTESY CRAYOLA; COURTESY SIMON AND SCHUSTER; COURTESY MISFIT; COURTESY STOWER

POPULAR SCIENCE

Why should you sign up for our newsletter?

REASON
#32

Our perspective on science is unique. Like you.

Sign up for the *Popular Science* editorial newsletter and each week you'll get the latest and greatest in tech reviews, science news, video, photography, and special offers.



GET THE LATEST CONTENT FROM OUR DIGITAL EDITIONS



Available on the App Store

THE FUTURE NOW

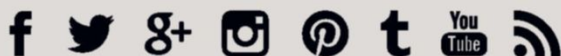
PopSci.com's news-reader app delivers all the content from PopSci.com in an easy-to-read format on the go.



Available on the App Store

Get up-to-the-minute news on cutting edge scientific research, gadgets and green tech. Save the stories to read, even when you're not connected, and filter them by your favorite topic.

STAY CONNECTED TO THE POPULAR SCIENCE COMMUNITY



Sign up today:

POPSCI.COM/NEWSLETTER

A CAR TO END TRAFFIC DEATHS



It's hard to get excited about safety. But Volvo's new XC90 SUV is so packed with life-saving technology, it's an exception. The car has a number of radar sensors and camera monitors used by its crash-avoidance software to keep passengers safe. If its computer system deems that a crash is imminent, it can alert the driver—or take control.

Short of turning the XC90 into a fully autonomous car, Volvo has used every driverless tool at its disposal. Radar-based cruise control keeps the vehicle a safe distance from traffic ahead. Cameras monitor traffic lines for automatic lane centering. If the car senses you're letting it drift, it vibrates the steering wheel. Radar scans your blind spots, so if you

attempt to merge into an occupied lane, an alarm sounds and lights in the side mirror flash.

A lot of that technology has found its way into other vehicles too. But the XC90 takes automation a step further, into the realm of artificial intelligence. It has software that learns your driving tendencies and, by monitoring your steering, braking, and acceleration patterns, can catch your mistakes before they turn deadly. The car compares your behavior to previous drives. So, if you start jerking the wheel, the center console will flash a text warning advising you to take a break. It's also the first SUV in the world to automatically brake if it's headed toward an oncoming car, cyclist, or pedestrian. The car does this with windshield-mounted radar that scans more



DESIGN OF THE MONTH

CHEVROLET-FNR CONCEPT

It's the car we've dreamt of for decades: With driverless operation enabled by roof-mounted radar, electric motors in each wheel, and a wireless charging system, the Chevrolet-FNR is a sneak peek into the future of the four-door family sedan. The concept also has iris-scanning security that recognizes the owner as well as front seats that swivel 180 degrees to face rear passengers.

than 600 feet ahead, night or day, rain or shine. If a collision is imminent, it will brake even if the driver is pressing the gas.

All of these innovations make the XC90 SUV the crown jewel of Volvo's audacious in-house pledge to eradicate death and serious injury in all of its vehicles by 2020. As such, it even protects you against other drivers' recklessness. Rear-facing radar monitors the speed and distance of vehicles behind you. In the event that you're about to be rear-ended, the XC90 tightens your seatbelt and applies the brakes so you don't strike vehicles ahead. Volvo also rearranged the bulky seat-adjustment motors and other hardware beneath the seats, making room for self-crumpling frames that direct energy away from passengers. The system reduces the risk of spinal injury by 30 percent.

Though it may not be the most powerful SUV out there, the XC90 has become a dominant force in highway safety. **ERIC ADAMS**



VOLVO XC90

Fuel Economy 20-25 mpg

Acceleration 0 to 60 in 6.1 sec.

Horsepower 316 at 5,700 rpm

Price starts at \$48,900

The XC90 is the first SUV in the world to automatically brake if it's headed toward an oncoming car.



Free Your Wi-Fi

PROBLEM

The number of Internet-connected devices in your home has exploded—iPhone, Sonos, Nest thermostat, app-controlled cat feeder. When they're all vying for Wi-Fi signal (or if your router's across the house), speed slows to a trickle. It's no wonder buffering keeps killing your *Orphan Black* marathon. "There's this last-inch problem," says engineer Nick Weaver. "We've got great pipes bringing faster Internet into our homes. But how do you get that speed to everything?"

SOLUTION

Weaver helped develop a smarter router called Eero (\$499 for three). Each Eero communicates with one another, creating a mesh network of up to 10 units. It switches frequencies to overcome interference caused by neighbors' networks, and boosts the signal at each node to combat distance and walls. Each system supports hundreds of devices, so your smart home won't get in the way of your binge-watching. **LINDSEY KRATOCHWILL**

54

Estimated percentage of Internet protocol traffic wireless devices will use by 2016 according to the 2014 Cisco Visual Networking Index



**BYE-BYE
BUFFERING**

Coming Soon

RISE OF THE (NEARLY) INVISIBLE WEARABLE



Tattoos say a lot about a person. They're about to communicate a lot more. A new wave of ultrathin, flexible stick-on sensors are entering the wearables game, promising to improve our lives with (even more) data.

For now adhesive mini computers are mostly in the "look-how-cool-it-is" phase. Google released a digital tattoo last summer that uses near-field communication (NFC) to unlock a Motorola Moto X smartphone. That's fun. But that's all it does. Other companies are jamming sensors and antennas into these nano-thin waterproof devices that could potentially save lives.



The wider promise of digital tattoos will come with health and fitness trackers. The SEEQ Mobile Cardiac Telemetry System, created by Medtronic, sticks onto a cardiac outpatient's chest and sends continuous heartbeat information to a medical monitoring service. The staff there can then analyze and send that data to a physician.

MC10, a company that specializes in stretchable electronics, will release the BioStamp system, which tracks heart rate, body movement, temperature, and other biometric data so people can monitor their own health at home. These sensors will provide real-time information for days on end—meaning smartwatches and wristbands might soon be a thing of the past. **ANDREA SMITH**

STEWART BUTTERFIELD WANTS TO KILL THE WATERCOOLER

EDITED AND CONDENSED BY MICHAEL NUÑEZ



As useful as it once was, email has become a hodgepodge of unorganized conversations. Add to that other tools—Twitter, Google Hangouts—that crowd our screens. Slack, an app that's conquering cubicles worldwide, stacks nearly all of your communications in one place. You can share files, direct-message, and search a project's entire history. So where is all of this communication headed? We asked Slack's co-founder, Stewart Butterfield.

continued on next page →



The Platform

Popular Science: Is email on its deathbed?

Stewart Butterfield: Email isn't going anywhere, but it's the lowest common denominator of communication. For one, every message is treated equally: family, work, friends, bank statements, and newsletters. They're hard to sort through. You also have this very tiny window into a conversation. With Slack, you can view a whole conversation thread—even before you joined it. That means that there's a huge increase in transparency.

PS: So are you trying to kill other communication apps?

SB: No. The company's mission is to make people's working lives simpler and more productive. One way you can do that is to reduce the overhead of constantly switching between programs. There is now one place where they all come together. So it's not that we want to eliminate people's use of those services—we don't. We want to make it easier for them to



urgent, they can override it. We're trying to build in tools that default to respecting people's time. People can concentrate when they want to. They can sleep their notifications for half an hour when they're in the middle of thinking deeply about something or if they're in a meeting.

PS: What happens if you want to ignore someone indefinitely?

SB: That's kind of a social problem, that should be solved between

“We’re already at the point where people sign into dozens of services each day just to get their work done.”

use those services. And one of the ways we make it easier is by having everything come together in Slack.

PS: Don't people resent this constant connection to work?

SB: It's definitely something we think about quite a bit. Recently a European tweeted, saying Slack is exporting the worst aspects of American culture, where people work all the time. But he was really asking for a feature to make it easier for people to manage their time better, and that's something we're working on.

PS: How so?

SB: For example, we are working on a “do not disturb” mode that kicks in by default and adjusts to your time zone. If someone sends you a message during that time, they'll be told that you're in do-not-disturb mode. If it's

employees. Although I think it is much easier to skip over someone's message when you see it's from them—to skip over it with your eyes—than to stop listening for 45 seconds while they speak it out loud. So it should be an improvement.

PS: Why has messaging become the killer app for big companies?

SB: Messaging is a fundamental social activity. If you're not using an app to send a message, you're uttering something with your mouth. And someone is listening with his ears. And when you stop talking, the message is over. It's the same form of conversation that has been around since the dawn of language. It's what two or more human beings do with one another. If you're having any kind of interaction, it's really just messaging. 

ADVERTISEMENT

Give us your
best shots
for a chance
to win an
awesome
photo
adventure



Transitions® adaptive lenses™ continuously adapt to changing light, bringing out the best in everything you see. So life looks more vivid, more vibrant, more true. Send us your most vivid and vibrant photos for a chance to win an all expenses paid **Mentor Series Trek** and have your winning image showcased in *Popular Science*.

Submit your images to
popsci.com/transitionscontest2015
from April 15–August 15, 2015

Transitions®
ADAPTIVE LENSES™

POWERED BY

**POPULAR
SCIENCE**

ARMOR FOR ROAD WARRIORS

For all the fun it offers, biking can be dangerous. In 2012 some 49,000 cyclists in the United States were injured in traffic accidents, and cyclist deaths from automobile crashes increased 16 percent between 2010 and 2012. But it doesn't have to be that way. New road gear can help riders avoid injuries—and crashes—altogether.
BERNE BROUDY



1 HELIOS HANDLEBAR

Helios has created handlebars—which are available in bullhorn, drop, and flat—with a built-in 500-lumen LED headlight and two taillights. The latter double as blinkers, which allows a rider to indicate a lane change or a turn without taking a hand off the bars. Using Bluetooth

Smart, the bars can connect to a smartphone, and rider-facing lights will pulse with turn-by-turn directions to keep eyes on the road, not a GPS device. During those long night hauls, the glow won't fade because the system's USB-rechargeable batteries run for up to 15 hours with lights on high. **\$280**

2 SCOTT RC PROTEC

A typical Lycra riding suit might be sleek and lightweight, but it shreds in a crash—along with your flesh. With help from Swiss textile maker Schoeller, Scott developed high-strength, break-resistant carbon yarn. The material is woven into cycling jerseys

and bibs where they're most likely to tear—the shoulders and hips—and then coated with ceramic. The fabric feels like Lycra, but the ceramic coating helps it slide across pavement, not stick to it, and the carbon prevents the fabric from tearing. Call it the road-rash killer. **\$125 (bib); \$145 (jersey)**

0.6

Estimated percentage of the American workforce who biked to work in 2013, which amounts to about 882,198 people

3 GIRO SYNTHE MIPS

Giro married aerodynamics with advanced safety technology in its new helmet—and it's still light enough for top racers. The company covered the side air vents with perforated plastic to eliminate drag and to force wind to stream past while maintain-

ing ventilation. Between the shell and the foam liner is the MIPS (multi-directional impact protection system) low-friction layer. In the event of a crash, the layer can slide on the head independently from the helmet's shell, which reduces rotational forces on the brain caused by angled impacts. **\$270**

gravity defyer®
ADVANCED FOOTWEAR TECHNOLOGY

NATURAL SHAPED SUPPORT
REMOVABLE ORTHOTIC

SOOTHES SENSITIVE SKIN
SMOOTH LINING AND COLLAR

G-DEFY SUPER WALK

VersoShock

ABSORBS HARMFUL SHOCK
U.S. PATENT #US8,555,526 B2

WIGGLE ROOM FOR TOES
WIDE EURO-STYLE TOE BOX

PROPELS YOU FORWARD
ROCKER TOE

They are awesome, saved my job... I work on my feet all day and used to pack my knees with ice, now I come home with no pain.
— Ron B.

VersoShock Patented Technology In Every Step

PROTECTION
Absorbs Harmful Impact

COMFORT
Stores Energy, Distributes Force

PERFORMANCE
Returns Energy

Feel better. Do more.

The stress and discomfort of being active and on your feet can destroy your quality of life. As you age, cartilage and other tissues that protect your joints become thinner and less resilient. Gravity Defyer® footwear helps protect your body and provide shock absorption from the ground up. Jogging running, walking – even routine standing, generate punishing impact. These forces produce lasting damage and wear on the body. Gravity Defyer footwear changes how our bodies

relate to the forces that prevent us from leading more active lives.

The Ultimate Shock Absorbing Footwear

With each step our patented shoe technology returns energy to you, to help you stay active and on your feet longer. A more active you means your muscles build strength and endurance, your body receives more oxygen and nutrients, and the heart and lungs work more efficiently. As your body gets more efficient you will have more energy to live the life you've always dreamed of!

Super Walk \$129.95

WOMEN • SIZES 5-11
Medium & Wide Widths

- BLK/PURP TB9004FBP
- WHT/PINK TB9004FWSP



MEN • SIZES 7.5-15

Medium & Wide Widths

- BLACK TB9004MBS
- WHITE TB9004MWS



**Scientifically
ENGINEERED
to DEFY
GRAVITY**

- ✓ Absorb harmful impact
- ✓ Stay comfortable & active
- ✓ Support & protect your body
- ✓ Stand & walk with greater ease

**WIDE
WIDTH
AVAILABLE**

**X WIDE
WIDTH
AVAILABLE**

**\$30 OFF
YOUR ORDER**

**PLUS
FREE SHIPPING**

Free Returns • Free Exchanges

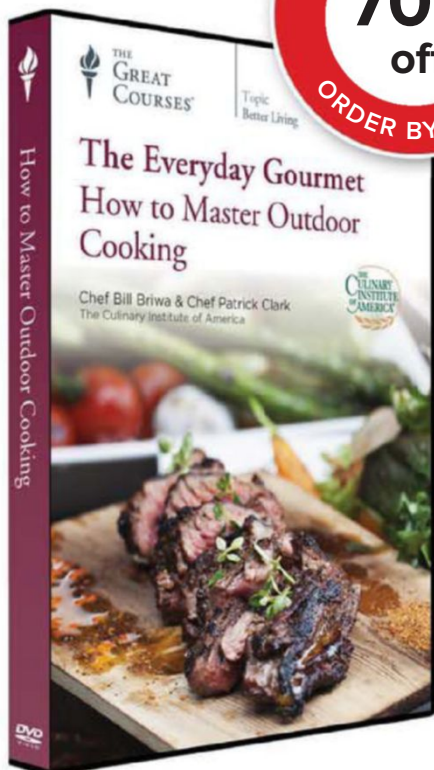
COUPON CODE: MC9GGY6

Call 1 (800) 429-0039

GravityDefyer.com/MC9GGY6

Gravity Defyer Corp.
10643 Glenoaks Blvd
Pacoima, CA 91331

*Offer valid for new customers only. Billing options selected during checkout. Shoes must be returned within 30 days and in like new condition for refund or exchange. Free shipping anywhere in the U.S. Credit card authorization required. See website for complete details.



Take Your Grilling Skills to the Next Level

On a pleasant day when family or friends are near, nothing beats firing up the grill for a great meal—yet most of us don't take full advantage of all the possibilities for outdoor cooking. Not only can the grill provide a savory seared crust on a juicy steak or add smoky flavor to barbecue chicken, grills can also enhance salads, side dishes, desserts, and a variety of meals beyond traditional burgers-and-hot-dog fare.

The **Everyday Gourmet: How to Master Outdoor Cooking** gives you the chance to boost your culinary repertoire and take full advantage of your “outdoor kitchen.” Taught by Bill Briwa and Patrick Clark, two highly acclaimed chef-instructors at The Culinary Institute of America, these 12 informative lectures are filled with detailed demonstrations of techniques and recipes from around the world that will liven up your summer meals.

Offer expires 07/16/15

THEGREATCOURSES.COM/5PS

1-800-832-2412

The Everyday Gourmet: How to Master Outdoor Cooking

Taught by Chef-Instructor Bill Briwa
THE CULINARY INSTITUTE OF AMERICA

Taught by Chef-Instructor Patrick Clark
THE CULINARY INSTITUTE OF AMERICA

LECTURE TITLES

1. The Art of Grilling
2. Grilled Vegetable Starters and Salads
3. Flatbreads and Pizza on the Grill
4. Grilling Seafood
5. Mediterranean-Style Grilling
6. Grilling Poultry
7. Latin American-Style Grilling
8. Grilling Lamb and Beef
9. Asian-Style Grilling
10. Grilling Veggie Savories and Sides
11. The American Tradition of Barbecue
12. Entertaining—Grilling for a Group

FREE COMPANION BOOK INCLUDED!

Beautiful and insightful, this **128-page full-color**, hardcover companion book features

- Full-color photographs
- Recipes
- Bibliography



The Everyday Gourmet:
How to Master Outdoor Cooking
Course no. 9271 | 12 lectures (30 minutes/lecture)

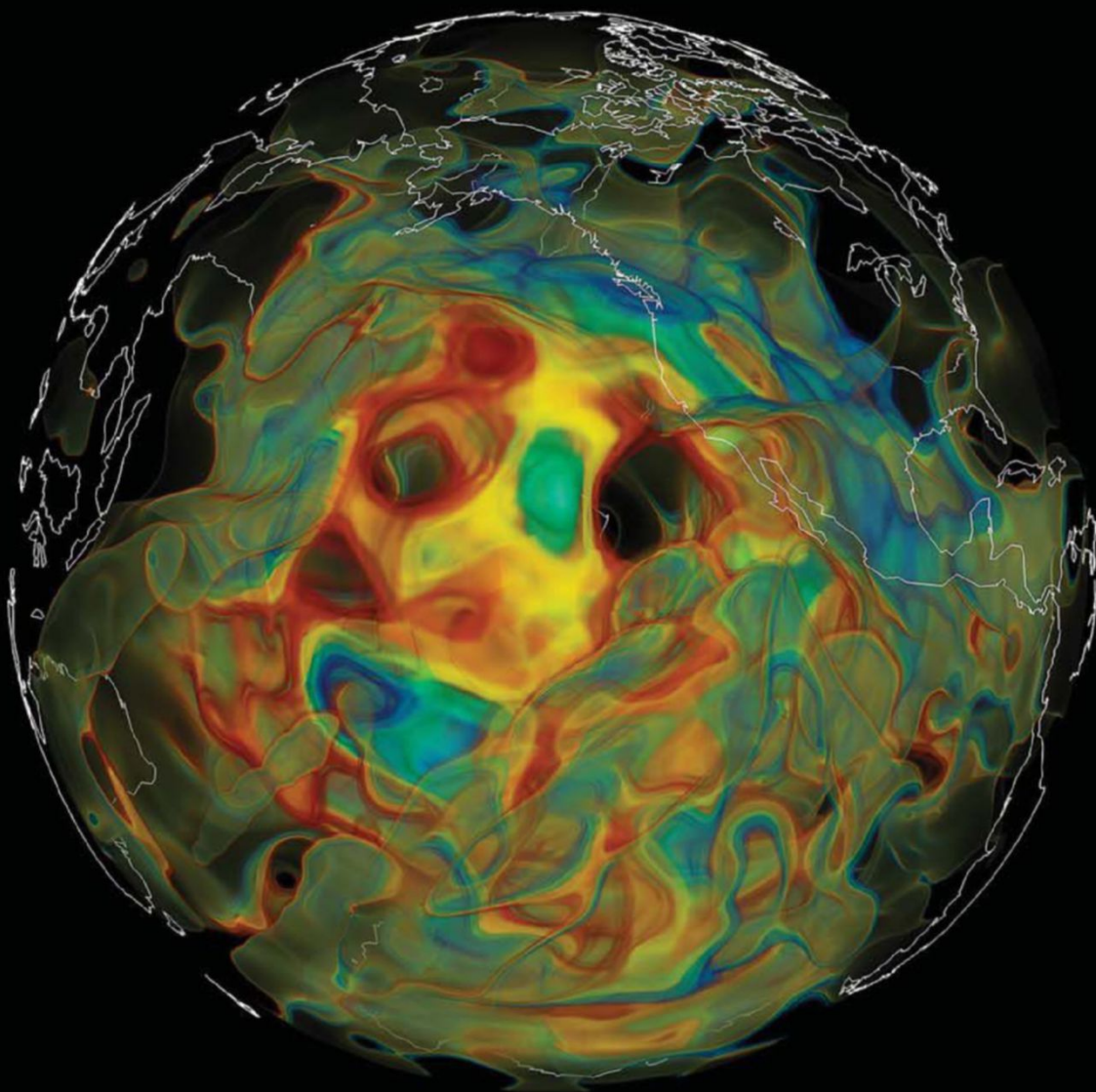
SAVE \$155

DVD ~~\$199.95~~ NOW \$44.95

+ \$5 Shipping, Processing, and Lifetime Satisfaction Guarantee

Priority Code: 108827

For 25 years, The Great Courses has brought the world's foremost educators to millions who want to go deeper into the subjects that matter most. No exams. No homework. Just a world of knowledge available anytime, anywhere. Download or stream to your laptop or PC, or use our free mobile apps for iPad, iPhone, or Android. Over 500 courses available at www.TheGreatCourses.com.



Inner Earth is a mysterious place. Its seismic rumblings spawn deadly earthquakes and volcanoes, often without warning. But a new model, powered by Oak Ridge National Laboratory's Titan supercomputer, analyzes reams of seismic-wave data to reveal the contents (and potential behavior) of Earth's mantle

in strikingly clear detail. Blue and green swirls represent cold, dense rock, through which seismic waves move quickly. Red and orange indicate hotter, younger rock that slows waves down. Seismologists can use the 3-D model to pinpoint hidden magma pockets or underlying tectonic plates. Someday it could also

250

Number of earthquakes, magnitude 5.5 and greater, analyzed to make this 3-D model

change the way engineers prepare for earthquakes. "Suppose you want to build a structure in Los Angeles," says Princeton University geophysicist Jeroen Tromp. "We can precisely simulate the kind of ground motions it might be subjected to and make informed decisions about building materials." **RACHEL FOBAR**

THE FOUR-DIMENSIONAL FUTURE OF STUFF

↓

Ours is a world of static objects, cut, cast, or forged for specific tasks. But let's say you opened an Ikea box, and the desk inside assembled itself. Or your water pipes shrank as the pressure decreased: no more weak showers, less wasted water. This is the 4-D-printed future, and labs are already striving to make it a reality.

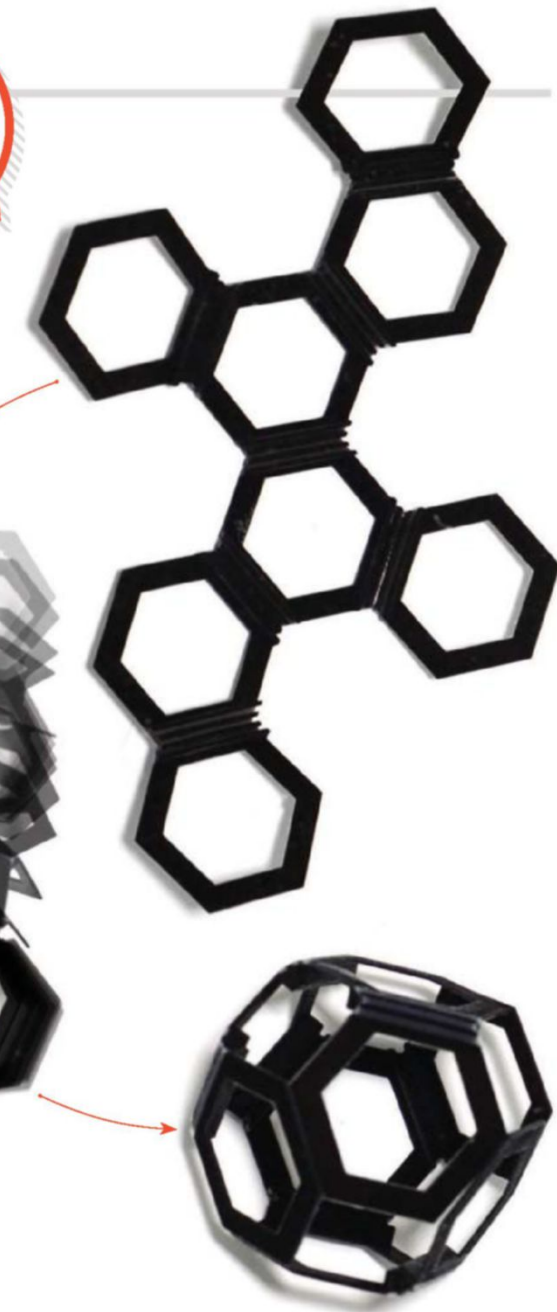
The tech builds on 3-D printing—with the added fourth dimension of time, across which objects transform. Skylar Tibbits, founder of MIT's Self-Assembly Lab, coined the term "4-D printing" in a 2013 TED Talk and showed how a straight plastic strand folded into the letters M, I, T when dropped in water.

The emerging research area is a sexy subset within the larger field of programmable matter, which also includes North Carolina State's self-folding origami polymers and Harvard's self-assembling robots. Whether 4-D-printed or not, programmable matter morphs in response to a contextual cue, be it light, heat, water, air pressure, electricity, or magnetic fields.

Funding from DARPA and the Army Research Lab has accelerated the work in the past two years. Engineers are now working toward self-assembling pop-up bridges, uniforms that adjust their insulation to individual biometrics, and camouflage that changes to match its surroundings. "It teases the imagination," says Jennifer Lewis, professor of biologically inspired engineering at Harvard. "But a lot more work has yet to be done to see

where the real killer application is going to come."

Meanwhile, the MIT lab focuses on everyday applications of 4-D printing. "Our strategy has been to collaborate with companies to get this into the hands of real-world people," Tibbits says. Last year, his team printed various materials onto a sheet of carbon fiber that, when exposed to heat, curled into a



4

Minutes it took
a 4-D-printed
carbon sheet to
fold itself into
a walking robot
at Harvard

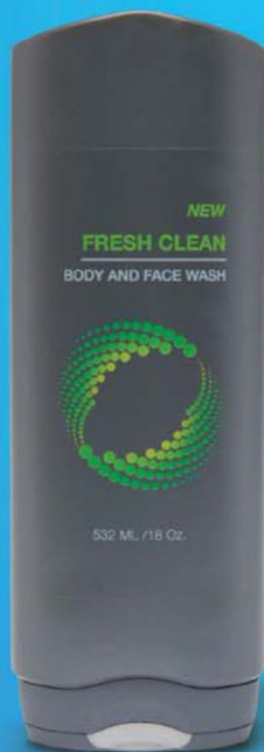
predetermined shape. The tech soon may enable extra-aerodynamic race-car spoilers and airplane wings.

"It changes the way products can be designed," says Junus Khan, founder of advanced-materials company Carbitex, which partners with the MIT team. "With materials that ship flat and undergo a shape change at the other end, we can consolidate 10 containers into two."

Programmable 4-D-printed materials will need safety measures baked in so bridges don't spontaneously disassemble and airplane wings don't freeze in the wrong position. But that doesn't deter Tibbits' group at MIT. "Our goal and our mandate," he says, "is to invent the future." **MEGAN MOLTENI**

"The vision is to print smart materials that can transform themselves. Like robots but without all the wires, sensors, and motors."

—SKYLAR TIBBITS, MIT research scientist



*I want
to be
a comb.
Recycle me.»*



IWantToBeRecycled.org



KEEP AMERICA
BEAUTIFUL

A WIND MACHINE YOU CAN CALL HOME



Windmills have dotted the Dutch countryside for centuries. But in densely populated cities, whooshing turbines are a tough sell. A new concept called the Dutch Windwheel could offer a silent, low-maintenance alternative.

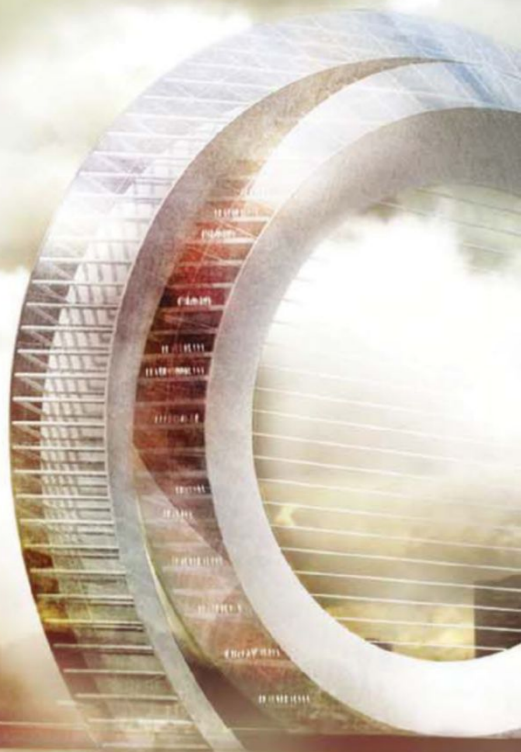
Whereas most turbines use spinning blades to turn the kinetic energy of wind into mechanical energy that generates power, the Windwheel cuts out the middle step. Its electrostatic wind-energy converter uses wind, water, and an electric field to directly produce a current.

So far, the tabletop prototype produces just 12.5

milliwatts—not enough to power a light bulb. And it's only 3 percent efficient, compared with a typical wind turbine's 45 percent efficiency. But if the technology advances on schedule, its creators say a 570-foot version could grace the Rotterdam skyline by the early 2020s.

People will be able to live, work, and dine inside the self-powered skyscraper as it cranks out 1 megawatt of electricity. "We wanted a 100-percent-sustainable building that serves as a platform for all kinds of innovations," says developer Lennart Graaff. **MARY BETH GRIGGS**

Sections of the glass facade will include augmented-reality touchscreens, adding a virtual layer of information to the panoramic views.



INNER RING

The building's design consists of two concentric rings atop an underwater foundation. The inner ring will be constructed of a steel frame and a glass exterior, which will provide sweeping views of the city for a restaurant, a seven-story hotel, 72 apartments, and office space located within.

OUTER RING

The outer ring will function as a massive Ferris Wheel, a la the London Eye. Its 40 glass cabins will take passengers above the city's world-famous architecture and below the surface of the canal.

PUMPS

The Windwheel will pump water directly out of the canal for use in its electrostatic wind-energy converter. The system can also operate using seawater or collected rainwater.

ELECTRO-SPRAYERS

Horizontal beams will stretch across the center of the Windwheel. Thousands of nozzles located along them will spray positively charged water molecules into the air. When wind pushes the droplets against the beams' high-voltage electric field, it will create a negative charge.

10

Anticipated
number of
years it will
take the Dutch
Windwheel to
pay for itself

CHARGING SYSTEM

The negative charge will form a current as the electricity discharges, much like when the negative charge that builds up in thunderclouds discharges to the ground via lightning strike. The electricity will then be converted from direct current (DC) to alternating current (AC) for use in the Windwheel or storage in an industrial battery.

LIGHT AND HEAT

Solar panels on the outside of the rings will generate additional energy. To warm the building, a so-called regional heat roundabout can deliver excess industrial heat from Rotterdam's port—the largest in Europe—through a network of pipes.

WE SEE YOUR PAIN

A new imaging technique could help end the mystery—and the stigma—of chronic pain



Nothing hurts Americans more than chronic pain. It's our single biggest health problem, affecting the lives of 100 million adults—more than heart disease, cancer, and diabetes combined. And that figure, from a 2011 Institute of Medicine report, doesn't even count kids in pain, veterans with devastating war injuries, or people in nursing homes.

Yet despite the fact that chronic pain is the primary reason Americans receive disability benefits, its one of the least understood afflictions. Medical schools teach doctors almost nothing about it, spending a median of nine hours on the topic over four years. The federal government puts absurdly few dollars toward research: \$4 a year for every person in pain versus \$2,562 for

44

Number of Americans who die every day from overdosing on prescription painkillers, according to the Centers for Disease Control and Prevention

patients' scans lit up in brain areas corresponding to where in the body they ached.

The new method produced dramatic images showing how glial cells—which are derived from the immune system but live in the nervous system—get activated in chronic-pain patients, ramping up the transmission of pain signals to the brain. “Over the past few years, we’ve seen this in animal studies,” says Marco Loggia, who led the MGH team. “But this is the first time we have proof that it works the same way in humans, and it’s a big step forward.”

The magnitude of these findings extends beyond the science. Many

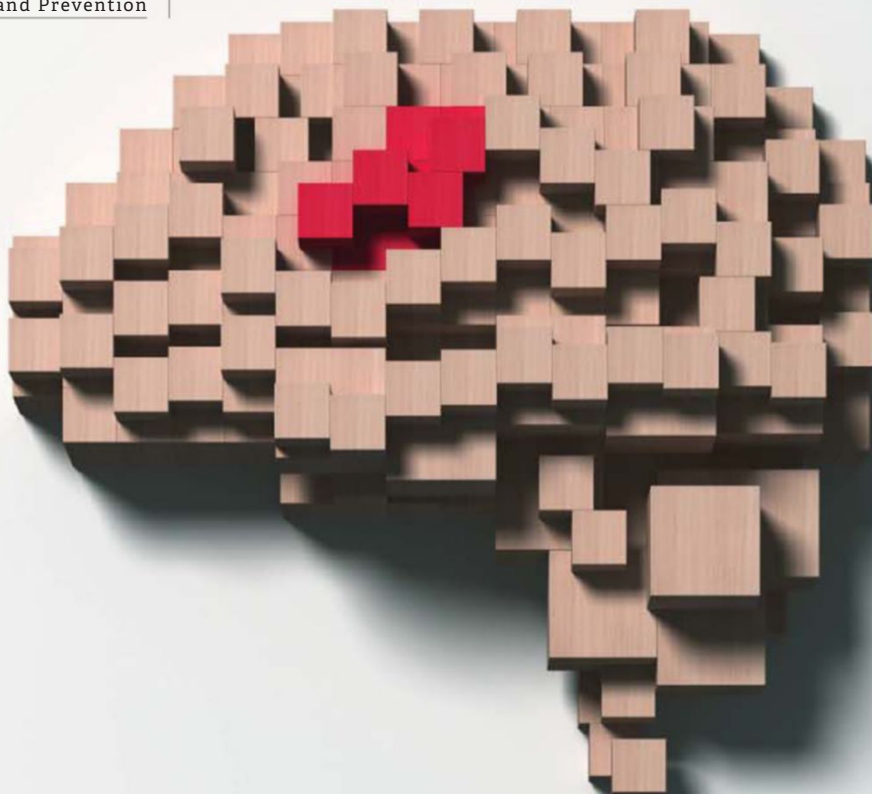
patients with chronic pain are mistakenly viewed by clinicians and society at large as drug seekers or hypochondriacs. Without a blood test or biomarkers for pain, they fight skeptics and suffer through trial-and-error treatments. This visible validation that patients’ pain is real will go a long way to ease the stigma.

But it's only a start. Now that we can see the activation of chronic pain, pharmaceutical companies should be aggressive with clinical trials to pursue new and novel treatments. “Pain can be reversed,” says Loggia. “In five to 10 years, we could potentially have a pill to do just that.” **JUDY FOREMAN**

The technique promises a better way to prove the existence of chronic pain.

every person with HIV/AIDS. One big reason for the lack of resources is that there's no objective way to confirm that pain exists.

The good news, finally, is that scientists from Massachusetts General Hospital (MGH) in Boston have unveiled a new brain-scanning method that allows doctors to see chronic pain in exquisite detail for the first time. The technique, a merger of PET (positron emission tomography) and MRI (magnetic resonance imaging), clearly identifies that a patient is hurting, and offers a significantly better way to diagnose chronic pain. In trials,



There is something
TERRIBLY WRONG
with the Home Security Industry

Hi. Maybe you've been broken into before, or maybe you haven't. But if you ever decide to protect your home against unfortunate events like that, you're in for a shock. We don't want to scare you off of protecting your home, because honestly, it's really important that you do it. But we feel responsible for sharing these facts with you: Most alarm companies take advantage of people who want to feel safe. They offer you a "free" outdated alarm, but then require you to sign a long-term contract full of nasty fine print. It's pretty sickening really...but this isn't going to be all bad news. There is a better way to protect your home—get a SimpliSafe home security system. Our founder, a Harvard engineer, studied the alarm industry and found all kinds of problems with it. He designed SimpliSafe to fix them, so you can be safe, without having to spend a fortune or sign any contracts. SimpliSafe is wireless, you can order it online, and it's easy to install yourself—anyone can do it. It fits any home, apartment, or business. And it's more affordable, more reliable, and stronger than just about anything else out there.

Most companies say "trust us" and then ask you to sign on the dotted line. We're asking you to let us prove that a SimpliSafe home security system is the smarter choice. Try SimpliSafe for 60 days. We think you'll love it. But if you don't, that's okay too. Return it to us for a full refund, no questions asked.

Visit SimpliSafe.com/Sci10



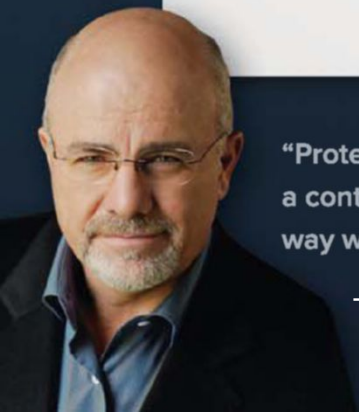
*You'll save 10% when you visit this page.
It's a special offer for Popular Science readers.*

"Protecting your family is important, but don't sign a contract to do it. Protect your home the right way with SimpliSafe. They are the good guys."

—Dave Ramsey, personal finance expert & New York Times Bestselling author of the *"The Total Money Makeover"*



SimpliSafe™



Temple Grandin

On how to raise resilient animals



In the 1990s, animal scientist and autism advocate Temple Grandin revamped the livestock industry to improve animal welfare and food safety—which meant lower costs too. Today, almost half of the cattle in North America is processed through a system she designed. Now, she's focused on a new challenge: how to reverse the damage done by decades of overly selective breeding.



"I think a lot of millennials feel a disconnect—they want to know where their food comes from, but a third of them have never been on a farm."

“

When it comes to breeding animals today, many factors contribute to what I call “biological system overload.” People are over-selecting animals until they get health problems. Hens, for example, are chosen for greater egg production and end up with osteoporosis. They put all their calcium in the eggs and there’s nothing left for their bones. Recent studies on pigs and other animals indicate that high-producing animals may have less resistance to disease. We’re seeing the consequences of that now.

It’s possible the current avian flu outbreak might be related to genetics. A study presented at the Midwest Poultry Federation Convention showed that wild ducks can live with avian influenza, while it kills high percentages of domesticated turkeys. So let’s breed some hardiness back into these animals. Let’s have a little less milk, and then we’ll have a healthy cow that will milk for four years instead of dying after two. We need to breed for optimum—not maximum—production.

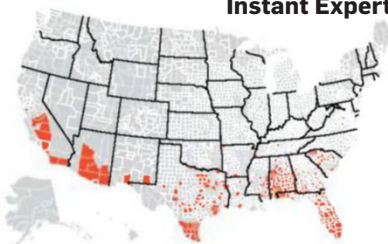
Another problem we need to address is that people are too far removed from the entire world of practical things, including farming. That can result in people making policy about stuff they don’t know anything about. Take lab-grown meat, for example. It’s a nice idea, but it’s not very energy efficient. A warm-blooded animal requires a lot of energy. If you want to grow food in the lab, why not grow scallops without the shells? We’ve got to get people connected to real, physical stuff—it teaches problem solving.” **AS TOLD TO LOIS PARSHLEY**

41

Chickens, in millions, infected with avian influenza between December 2014 and June 2015. The USDA says it’s the worst U.S. outbreak ever.

MOSQUITOES DESIGNED TO SELF-DESTRUCT

Red denotes the counties in which the invasive *Aedes aegypti* mosquito has been detected at some point, but it has likely gone unreported in many others.



5

Oxitec is planning trials for the Keys this year, pending approval from the FDA and a local board. Concerned residents are lobbying to block them, fearing potential unforeseen consequences of releasing the genetically-altered insects into the environment.

6

Dengue's not all. "The chikungunya virus can mutate and is permanently established in the Americas," says Stephen Higgs, director of the Biosecurity Research Institute at Kansas State University. More than 2,300 travelers brought the disease to the United States in 2014, and Florida counts 11 locally transmitted cases. "We don't know what it'll do next, but it could become widely distributed in the U.S.," Higgs says.

7

Wiping out the mosquitoes isn't a perfect solution, though. "Even if it is effective, this technique has shown it can reduce mosquito populations, not disease," says Durland Fish, an epidemiologist at Yale University. These viruses can be wily. "It is not one and done." **MATT GILES**



Every year, mosquitoes infect 400 million people with dengue fever, causing severe headaches and joint pain. Since a 2009 outbreak in Key West, the Florida Keys Mosquito Control District has spent \$1 million a year to try to curb the primary vector: *Aedes aegypti*. Last July, another mosquito-borne virus reached U.S. shores: chikungunya. Now officials are considering a radical—and highly controversial—approach to control the spread of tropical disease: genetically-modified mosquitoes.



The modified mosquitoes, code-named OX315A, eliminate more than 90 out of every 100 wild mosquitoes.

"I think this is one of the greatest ideas in the history of pest control."

—Rebecca Trout Fryxell, entomologist at the University of Tennessee

1

The *Aedes aegypti* mosquito thrives in urban settings and is highly resistant to insecticide. Plus it almost exclusively bites people. "It has successfully spread around the world on the back of human transport," says Andy McKemey of insect-control company Oxitec. "It is the rat of the insect world."

2

To keep populations in check, Oxitec genetically modified the insects. They injected mosquito eggs with synthetic DNA that codes for a self-limiting gene. This doesn't kill the mosquitoes outright, but it prevents their offspring from reaching adulthood to mate.

3

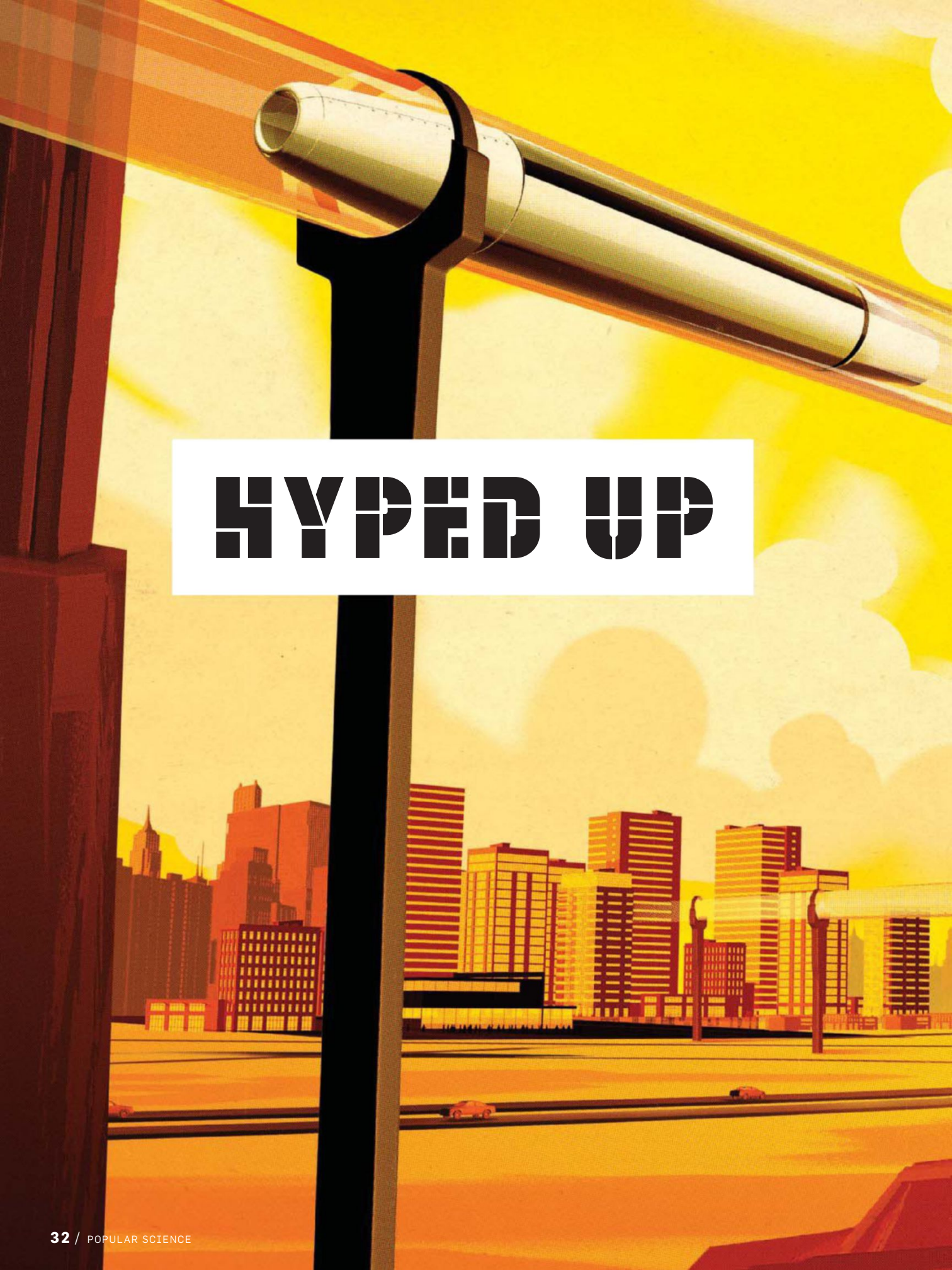
"We release sufficient numbers of males to out-compete locals," McKemey says, "and that gene is passed to their progeny." Then additional releases of modified mosquitoes ensure that the wild populations are diminished enough to no longer pose a threat.

4

Oxitec has conducted trials with its modified mosquito in dengue-ridden regions of Panama, Brazil, Malaysia, and the Cayman Islands. The results show population suppression rates above 90 percent—far greater than the typical 30 percent achieved with insecticides.

5,000

Rough number of modified *Aedes aegypti* mosquitoes released per resident during Oxitec's 2014 Panama trial



HYPED UP



ELON MUSK PROPOSED A RIDICULOUSLY AUDACIOUS FORM
OF TRANSPORTATION. NOW, STARTUPS ARE RACING TO
BRING THE HYPERLOOP TO LIFE.

by **James Vlahos**

ILLUSTRATION BY TAVIS COBURN

MAYBE

it was the Guns N' Roses pumping from the speakers. Or maybe it was the spell of

Dubai itself, a newly minted megalopolis whose explosion from the Arabian sands screamed that the past was dead and the future had arrived. Whatever it was, when Dirk Ahlborn launched into his speech at the Middle East Rail conference in March, he basically gave the roomful of executives the finger. "There hasn't been any real innovation in the rail industry for—I don't know how long," he said. "Either disrupt yourself or you are going to be disrupted."



The hyperloop concept isn't just a fantasy, says Hyperloop Transportation Technologies' founder Dirk Ahlborn, shown here near the Dubai Metro. "It's not like we want to invent an antigravity device."

The audience sitting attentively in the convention hall included men in traditional dishdashas and women in black abayas. Other attendees wore suits and ties or even heels and short skirts. Together they formed the industry's elite, people who built trains and ran railways around the world, while Ahlborn was the CEO of a startup, Hyperloop Transportation Technologies (HTT), that hadn't carried a single passenger or laid an inch of track.

But restraint doesn't come naturally to Ahlborn, who wore, beneath his black suit, a white shirt open several buttons from the collar. Tall, with thinning brown hair and ruddy cheeks, Ahlborn began to pace the stage, TED-talk style, as he explained his vision for the future of transportation. "What is the hyperloop?" he

asked. "It is a capsule, full of people, in a tube, elevated on pylons, going really fast. It's that simple."

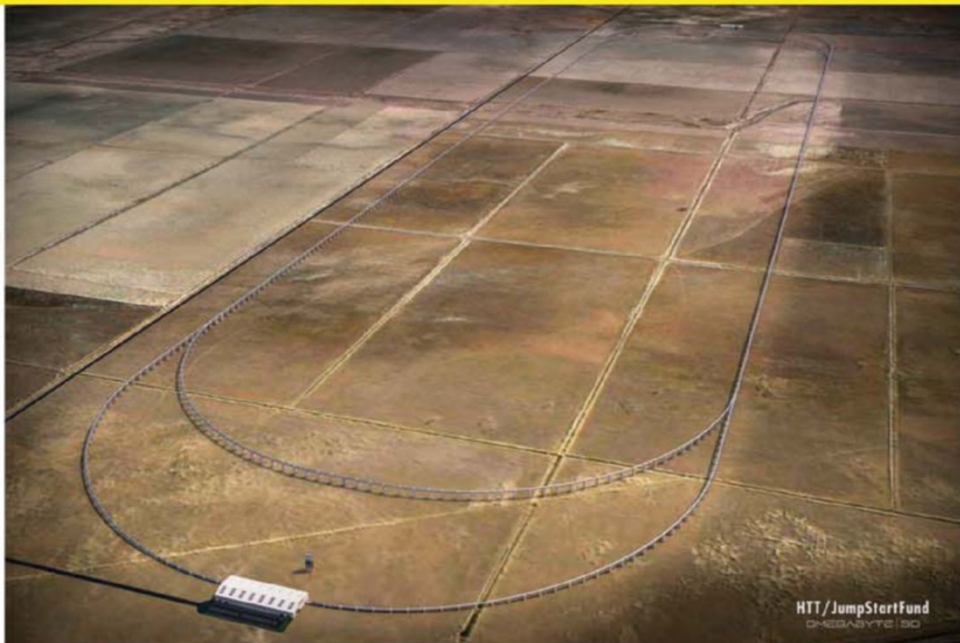
Hyperloop capsules would use either a magnetic field or a continuous blast of compressed air to float above the bottom of the tube. Pumps would remove most of the tube's air, creating an extremely low-pressure environment. Minimal air means minimal friction, so the capsules would travel at up to 760 miles per hour, powered entirely by solar panels. "How would your life be if you could travel 600 kilometers in half an hour, with a ticket price of \$30?" Ahlborn asked. "If we achieve that, we really change the way we live."

Ah, the hyperloop—the same scheme that Elon Musk, the CEO of SpaceX and Tesla Motors, famously proposed in a white paper

back in August 2013. The pronouncement incinerated the Internet, with some awe and lots of *are-you-kidding?* The technical challenges, while daunting, were potentially solvable, engineers opined. But economists estimated that Musk's projected cost of \$6 billion to connect San Francisco and Los Angeles was lowballed by a factor of 10 or more, not least because the cost for acquiring land for the route was grossly underestimated. The hype faded—but the outlandish idea was still alive.

By the end of the year, Ahlborn had launched HTT. In June 2014, Hyperloop Technologies (HT) entered the field, founded by Silicon Valley venture capitalist Shervin Pishevar and former SpaceX rocket engineer Brogan BamBrogan. And this past January, Musk himself was back, tweeting his intention to build a hyperloop test track, possibly in Texas. The two startups announced their own test-track plans shortly thereafter, with both hoping to break ground by 2016. The race for near-supersonic land travel was on.

Hyperloop proponents face uncountable hurdles—technological, political, and financial. But the massive challenges seem to inspire rather than intimidate them. The hyperloop, they believe, will be an entirely new form of transportation, one that is quicker, cheaper, and more fuel efficient than anything that has come before. "If you think about the things that have been most exciting in history, that have captured headlines, it's humans taking flight, Lindbergh



Hyperloop Transportation Technologies plans to break ground in 2016 on a 5-mile track that will serve Quay Valley, a real-estate development in California.

It will start carrying passengers as soon as 2018.

crossing the Atlantic, going into orbit and to the moon," said XPRIZE Foundation chairman and CEO Peter Diamandis, who sits on HT's board of directors. "We revel in moving people faster and farther than ever before, and hyperloop is in that same vein but in a different dimension."

In Dubai, Ahlborn finished his presentation, and the audience applauded enthusiastically. He stepped down from the stage, and a man in a traditional white robe approached. I saw that he was Saqqaf AlAttas, a manager with Etihad Rail DB, which oversees operations for the United Arab Emirates national railway. He shook Ahlborn's hand. "Everything starts with a dream," AlAttas said. "And from what I saw, the hyperloop is not just a dream. It is already here."

AHLBORN

cut a Tony Stark-like figure as he strode through the convention hall after he spoke. The place looked like a giant IKEA showroom devoted to the sole purpose of selling trains. A maze of avocado-colored pathways funneled attendees between brightly lit displays featuring track ties and rail wheels. A German native who had also lived in Italy before settling in Southern California, Ahlborn chatted fluently with vendors in multiple languages. His manner was aloof, his comments sometimes barbed. "Is there anything new at this show?" he asked a person peddling software. "Has there been anything new in the past 10 years?"

In reality, Ahlborn is not a deep-pocketed tech magnate—at least not any longer. Sure, the 38-year-old had been an entrepreneur since he was 18. And he had made millions as, among other things, the CEO of a pellet stove company. Subsequently, though, he lost his fortune when real estate investments tanked in the financial crisis. While he may have looked like Stark in Dubai, back home he was renting his place on Airbnb.

Ahlborn runs HTT on a shoestring as well. The company had been launched on another one of his ventures, JumpStartFund, an online crowdsourcing platform that enables people to propose companies and then build communities of volunteers to bring those ventures to life. Ahlborn posted the hyperloop idea shortly after Musk announced it, and was overwhelmed by the response. More than 300 volunteers have signed contracts

to officially join the startup, working at least 10 hours a week in exchange for stock options should the company make it as far as an IPO. They include engineers, business executives, and human resource and marketing professionals, and they form HTT's entire staff. They also maintain day jobs at companies like Northrop Grumman, Airbus, and Cisco, and attend universities like UCLA, Stanford, and Harvard. With any profit years away, they are united less by materialism than by near-religious faith in the hyperloop's potential. The team members envision themselves as builders of the first railroad, as pilots of the first plane. "We don't necessarily require that you have the right credentials," Ahlborn says, "but we require that you have the passion."

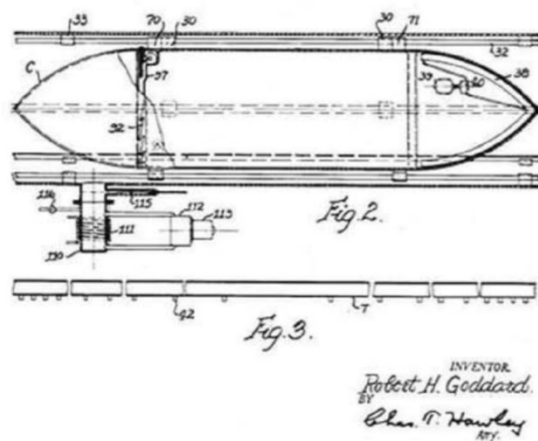
Ahlborn scouted the trade-show floor for new converts. "We are a company of the people," he explained to one prospect. "We're crowd-powered." The message resonated. A software engineer agreed to do a passenger-flow simulation for free. A building-materials vendor suggested alternatives to concrete. Paul Priestman, who recently designed the cars for the London Underground's New Tube project, said his company could help with visual concepts. And Stephen Bradbury-Knight, a vice president of mobility and rail for the security-services provider TÜV Rheinland, offered to think about safety standards.

The next day, Ahlborn was joined by an HTT team member, a former Italian pop star-turned-tech entrepreneur, Gabriele

“The team members are united by near-religious faith in the hyperloop’s potential. They envision themselves as builders of the first railroad, as pilots of the first plane.

"Bibop" Gresta. The three of us hopped onto the new Dubai metro and rode through a canyon of geometrically contorted skyscrapers. The ice-pick tip of the Burj Khalifa, the world's tallest building, spiked above the skyline. We disembarked at the Palm Jumeirah, a tree-shaped archipelago of artificial islands, and walked into the perfumed lobby of an expensive hotel. There we met a jocular Italian named Giuseppe Ugge, whose job, he told me, was to introduce the United Arab Emirates royal family to foreign business executives with ideas to sell.

Ahlborn was ready. Dubai would be the perfect location for a hyperloop, he said. Land is expensive in California—as it is near every major city in the United States and Europe—and navigating the gauntlet of regulatory and political hurdles will take years, if not decades. Dubai, in contrast, has abundant empty land, and a massive project can be built there with the say-so of a single person: Sheikh Mohammed, the emir of Dubai. Also, Ahlborn reminded Ugge, Dubai will host the World Expo in 2020. Since the first world's fair in 1851, the expo has introduced millions of people to such technological wonders as the telephone, typewriter, escalator, and talking films. Dubai, Ahlborn



Robert Goddard proposed the vacuum train as a freshman at Worcester Polytechnic Institute in 1904. As he wrote later, "The possibilities of this method of travel are startling...a running time from Boston to New York of ten minutes is perfectly possible."

proposed, could be where the hyperloop makes its world debut.

Send me your plan, Ugge said, "and if it is good, we can introduce you."

computers and scribbled on whiteboards.

Whereas HTT has no office, no salaried employees, and essentially no cash resources, HT has a full-time staff of more than 30 people and \$10 million in seed funding, which it raised in just a few months. The company aims to hit \$80 million by the end of this year. (Pishevar, who is well on his way to becoming a billionaire thanks to investments in companies like Uber and Airbnb, pledged to put up half the money if needed.) The company has also recruited a well-connected board of directors. In addition to Diamandis, it includes political operative Jim Messina, who masterminded President Obama's 2012 campaign, and entrepreneur David Sacks, the founding COO of PayPal.

It was April, not long after I'd returned from Dubai. BamBrogan strode up, a lanky 43-year-old whose thick mustache and twinkling eyes made him look like the ringmaster of some steampunk circus. When I



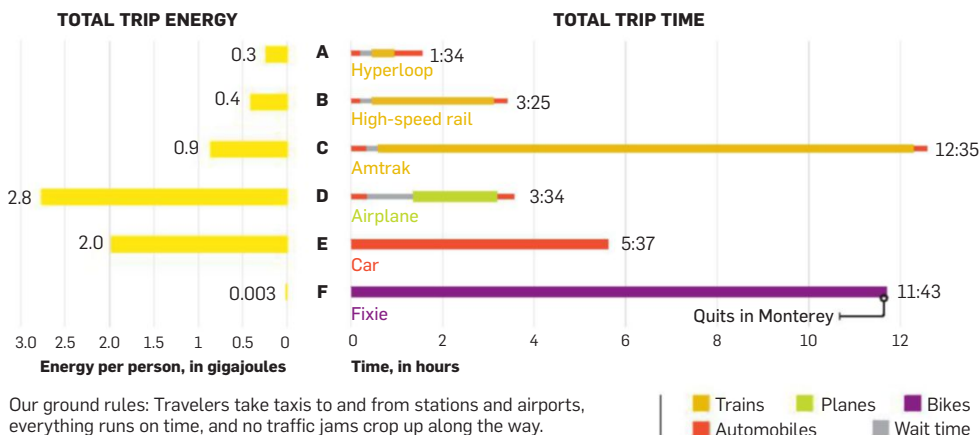
the end of an industrial block in Los Angeles, past the PlayPen strip club and a homeless man who snoozed facedown amid a collection of marijuana canisters, I entered the headquarters of BamBrogan and Pishevar's Hyperloop Technologies. I blinked at the incongruent scene inside—6,500 square feet of open warehouse illuminated by skylights and framed by exposed brick walls. Employees tapped at

How the Hyperloop Stacks Up

Looking to get from San Francisco to Los Angeles? Here's how long the trip could take you via current (and future) forms of transportation.

Hyperloop might be fast, but riders will still need to reach a station, board a capsule, and travel to their final destinations. Those extra elements will slow down the 30-minute dream. But will hyperloop beat other options anyway?

To find out, we engineered an imaginary race. Six people leave an apartment in San Francisco's Mission District and meet in Highland Park, Los Angeles, to settle a dispute over the best tacos on the West Coast. Each will take a different mode of transit: a train, a plane, a car, the hyperloop, the (also hypothetical) California High-Speed Rail—and a fixed-gear bicycle, the single-speed mainstay of hipster transport. **KATIE PEEK**



asked about the skeleton key dangling from a lanyard around his neck, he cryptically pronounced, "This is the key to anything but not everything." Mischievous air aside, BamBrogan is a serious engineer: At SpaceX, he had led the early design of the Dragon spacecraft and the upper-stage engine of the Falcon 1 rocket.

The hyperloop, BamBrogan told me, was actually the latest iteration of an idea that has tempted engineers for more than a century: Put a train in a tube and remove most or all of the air. Rocketry pioneer Robert Goddard proposed the basic plan for what is known as a vacuum-tube transportation system in 1904. In 1969, the U.S. Secretary of Transportation wrote in *Popular Science* that the government was studying several "tube-vehicle system" concepts. Both HT and HTT are now

pursuing the same notion.

The companies envision depressurizing the hyperloop tube to about 100 pascals—not a total vacuum, but 1/1000 of the natural atmospheric pressure at Earth's surface. With so little air to push out of the way, the capsule requires very little energy to attain near-supersonic speed. Solar panels atop the tubes, charging the equivalent of about five Tesla Model S batteries per capsule, should provide sufficient power to run the entire system.

Engineer Sandeep Sovani, working independently from HT and HTT, recently ran hyperloop airflow simulations for the software company Ansys. The overall concept is valid and has great promise, Sovani says. "I think tube transportation technologies are to this century what railways were to the 19th century."

Implementing the relatively simple idea, however, will be tough. To move the capsules through the tubes, HT is investigating the use of linear induction motors, which would use the repulsive magnetic force between the hyperloop capsule and the tube floor to generate propulsion. Subway systems and roller coasters already use such motors, so BamBrogan initially thought he could buy the primary components off the shelf. But because those systems top out at around 70 miles per hour, not 700, existing technology probably won't work. "We would rather invent as few things as we need to," BamBrogan said, "but it looks like we may go in the direction of customizing a system."

At full speed, hyperloop capsules won't use wheels, so HTT may generate a magnetic field in order to levitate them. This is a proven technology: Witness maglev projects like Shanghai's Transrapid; its trains can hit 268 miles per hour. The problem is cost. Maglev trains are more expensive to build than conventional ones—according to one source, Transrapid cost \$63.2 million per mile of track—and if HTT has a radical idea to slash that expense, Ahlborn hasn't revealed it yet.

Both companies are also investigating a different strategy: air bearings. Jets of air blasting down from beneath the capsules would enable them to skim through the tube like a puck streaking across an air-hockey table. Computer designers currently use air bearings to float the spinning platters inside hard drives, and manufacturers use them to levitate heavy objects in factories so they are easier to manipulate. Air bearings make theoretical sense in vehicles too—they're low friction and don't wear out the way wheels would. The U.S. Air Force successfully tested air bearings on rocket sleds back in the 1960s. HT could learn from those experiments, BamBrogan said, but the sleds traveled

on a monorail track and so were a fundamentally different type of vehicle. The hyperloop's bearings, like its motors, will need to be invented almost from scratch.

Since a hyperloop tube would not be totally depressurized, the air that remains poses yet another engineering challenge. If the capsule fits snugly inside the tube, it would have to push an increasingly high-pressure mass of air ahead of it, a phenomenon known as pistoning. (Imagine a plunger pushing liquid through a syringe.) One solution, Musk suggested, would be to make the tube's diameter roughly twice the width of the capsule so some of the air could pass around it. He also proposed mounting a giant compressor on the front of the vehicle. The compressor would suck in air and pack it down to perhaps 1/20 of the volume, then both blast it out through the air bearings and pump it into the tunnel behind the capsule.

HT is using Musk's 2-to-1 tube-to-capsule ratio as the starting

The finding didn't invalidate the hyperloop concept, Justin Gray, a member of the NASA team, explained when I phoned him at Glenn. But if a tube hundreds of miles long needed to be twice as wide as projected, the cost of construction would balloon.

Throughout my visit, BamBrogan ping-ponged between an entrepreneur's brashness and an engineer's caution. "I don't think anybody thinks that hyperloop is a bad idea," he said. "But a

SILICON

Beach, located across town from HT's headquarters, hosts Google, Yahoo, Snapchat, and hundreds of other tech startups. Long before those companies, though, the area was home to a different kind of entrepreneur: the aviator Howard Hughes. The cavernous wood-paneled hangar where he once built planes now holds a full-scale hyperloop simulator. Eight feet wide and ringed by glowing white lights, it looks like a giant Cheerio crossed with a portal to the afterlife. I stepped into the capsule and sat down next to Marta Nowak, an architect involved in the design. "OK," she said, "are you ready to take a ride?"

The lights in the hangar dimmed. Atmospheric music began to play, with piano arpeggios dancing gracefully on top. "We are still in the station; the doors just closed," Nowak said. Then, she informed me, the capsule began accelerating. Hyperloop critics have complained that the ride would be nauseating—"New Super-Fast Transport System Powered by Passengers' Screams," *The Onion* quipped. But according to Nowak, passengers would actually feel and hear very little due to the gradual acceleration—it would take several minutes to reach full speed—and broad turns. The experience would be like flying in a plane at 30,000 feet, only quieter. The lighting in the simulator was low and purplish. "We can look back and see our fellow passengers," Nowak

“The calming vibe was carefully engineered. First-time passengers, after all, would be anxious about riding a bullet through the barrel of the world's longest gun.

point for its design. The company is also studying how to incorporate an air compressor. Josh Giegel, an HT engineer, showed me a tiny piece of twisted metal that he had recently 3-D printed in the possible shape of a hyperloop compressor blade. He would soon be testing it in a wind tunnel behind the office.

But when aerospace engineers at NASA's Glenn Research Center did an independent analysis of the hyperloop concept, they concluded that to prevent pistoning, the tube would likely need to be four times the width of the capsule, even with a compressor.

few people do think hyperloop won't exist or can't exist." That's why the company is gunning to build a test loop as soon as possible. A successful demonstration, BamBrogan said, would be "our Kitty Hawk moment, when the thing flies."



Shervin Pishevar and Brogan BamBrogan founded Hyperloop Technologies. The startup's new transportation electronics laboratory will use an induction motor in simulations of the hyperloop's propulsion system.

The Pistoning Problem

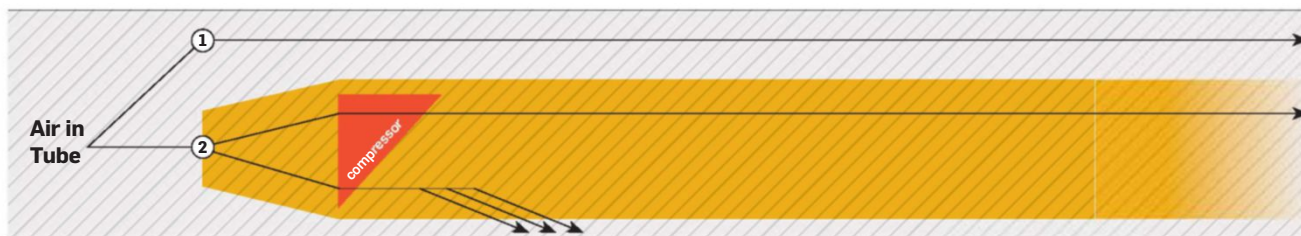
Air remaining inside the hyperloop tube will pile up in front of the capsule and slow it down. NASA engineers analyzed a potential two-part solution.

1) Let It Blow By

Musk proposed making the tube nearly twice as big as the capsule. This would allow enough room for some, but not all, of the air to flow around the capsule as it speeds through at Mach 0.99.

2) Pump It Through

A compressor can suck air in and pump it out below and behind the capsule. But the air must first be slowed by a diffuser to Mach 0.6. Higher speed requires a bigger diffuser—and a larger capsule.



Bottom line: The tube might need to be four times the width of the hyperloop capsule, and the speed should be capped at 620 mph, or roughly Mach 0.80. That would raise the construction costs and add five minutes to an LA to San Francisco trip.

said, and I glanced over my shoulder at a dozen rows of seats extending behind me.

Hyperloop tubes are solid, eliminating any view, so instead of windows, the builders installed flat-panel displays on the capsule walls. They started out showing starry skies, and then the cabin brightened and the scenery changed to farmland, a lake, and a forest streaking by. When we reached our destination, I felt like I had time-traveled in a high-end spa. Nowak said the calming vibe was carefully engineered. First-time passengers, after all, would be anxious about riding a bullet through the barrel of the world's longest gun. "If people try the hyperloop once and like it, they are going to take it again," Nowak said. "But if they don't...."

The mock-up of the

capsule—a Styrofoam-and-plywood vessel augmented by a video projector—had been built by post-graduate students in the department of Architecture and Urban Design at UCLA. Under the direction of architects Craig Hodgetts and David Ross, the students had also created computer models of the station and capsules. The UCLA team collaborated with HTT as part of a program called Suprastudio, which pairs students with industry partners to give them real-world expertise.

I exited the simulator feeling sublime. But to skeptics, such as transportation blogger Alon Levy, my experience might be emblematic: The hyperloop was a mirage—unfeasible and expensive. What's more, they said, Musk may have had ulterior motives in proposing the concept in the

first place. He makes no secret of his disdain for California's plan to build a \$68 billion conventional high-speed rail line. Levy and others suspect that Musk's objective may have been to erode support by touting the much-sexier hyperloop—*look, folks, only \$6 billion for a supersonic levitating train!*

Whatever Musk's motivation, the idea is now bigger than him. That's why a UCLA student told me that she and her friends spent 14 hours a day toiling on prototypes, why BamBrogan and Pishevar are investing so much money, and why HTT's volunteers comprise something that is more than a company and closer to a movement. They are all infected with the Walt Disney strain of futurism in which you try to engineer a bigger, brighter tomorrow, not merely another smartphone app. In the capsule I asked Nowak if she would be excited to ride for real. "Absolutely," she said. "We could walk right now to the station, and in 30 minutes have dinner in San Francisco. That's crazy!"

After the ride I wandered through a door in the rear of the workspace and into an adjacent hangar. It was even more vast—315,000 square feet of silence and shadows. A cathedral of audacious engineering, this was where Hughes had built the Spruce Goose, whose 320-foot wingspan has never been surpassed.

The plane was flown only once, for a mile, before it was mothballed. An expensive, widely mocked boondoggle, it serves as a cautionary tale for the hyperloop's creators. But the Spruce Goose, wider than a football field and built almost entirely from wood, is also an inspiration. You might not succeed at building something crazy, something so monumental and complex that most people say it can't be done. But it is hard to resist the impulse to try. 

THIS SUMMER'S SCI-FI
MOVIES ARE SO
BIZARRE, THEY MUST BE
FICTION. RIGHT?

WEIRD SCI-FI



THE QUESTION

CAN GENETIC ENGINEERING CREATE KILLERS?

Inspired By: *Indominus rex*, the dinosaur superpredator that profiteering scientists cook up in *Jurassic World* (June 12); the title character from *Hitman: Agent 47* (August 21), who was genetically engineered to be an ultra-efficient killer

THE ANSWER

Good news for prey: Genetic engineering is woefully ill equipped to produce bespoke killers of any kind. That's because building a life-form is a messy and unpredictable process. "It's quite easy to disrupt development and cause problems," says Michael Deem, a bioengineer at Rice University. Often, modified creatures die for reasons that are never identified.

That means it's also too early to wield genetic engineering for good—but that hasn't stopped scientists from wading into ethically dubious waters by trying. In China, researchers recently edited the genes of a nonviable human embryo. While targeting the gene responsible for a potentially fatal blood disorder, they triggered a number of unexpected mutations. "They argued that they never intended to take the experiments all the way to a human being," says Paul Root Wolpe, director of the Emory Center for Ethics. "But in fact, these exact experiments are what you have to do to perfect these technologies."

Today, the surest path to genetic modification is likely an indirect one. For instance, studies have shown that microbes in the gut appear to affect things like mood and obesity. Modifying the microbiome might lead to more-levelheaded soldiers or more-fit humans in general. DARPA has funded two attempts to develop genetically engineered blood—one to function as a universal blood type, and another to deliver antibiotics. As Wolpe points out, the military has punished soldiers for refusing similar treatments, such as injections to protect against bio-agents. The battlefield could be the perfect ethical no-man's-land for the dawn of gene-based human enhancement.

BY ERIK SOFGE

PHOTOGRAPHS BY JONATHON KAMBOURIS





THE QUESTION

WILL MIND TRANSFER EVER HAPPEN?



Inspired By: *Self/less* (July 10), in which a dying billionaire “sheds” his mind into a younger man

THE ANSWER

It's tempting to imagine the brain as a biological computer, with the tissue as hardware and electrical activity as software. If that were the case, mind transference might be technically feasible (albeit ethically fraught), at least pending the development of some extremely advanced electrode arrays. Extricating mind from matter, though, can't be done. “The self is in the structure,” says Charles Higgins, a University of Arizona neuroscientist and electrical engineer. “It's in the interconnection of 100 billion neurons, and in the individual shape of neurotransmitters and receptors.” Even if surgeons could successfully transplant a brain, they would have to transfer the spinal cord

as well, or risk stripping the subject of a lifetime of muscle memory.

One workaround, says Higgins, could involve cloning. A clone with a structurally identical central nervous system could perhaps be stimulated with electrical signals that mimic the original. However, human cloning is itself still the stuff of science fiction, and neuroscientists have so far mapped the connections between only about 100,000 neurons at once—the equivalent of a worm or fish brain.

What scientists can do today is rewire the brain *in situ*. For example, Columbia University researchers implanted deep-brain stimulators in people with severe treatment-resistant depression. When they sent electrical impulses to precise areas, the patients' symptoms instantly diminished. After two years, one person reported that her depression had disappeared completely. As scientists stimulate more patients' brains, they could unlock other possibilities. “We might accidentally discover, as we're trying to stop someone's epileptic seizure, that we can stimulate a pattern in the visual cortex to create a memory,” says Higgins.

So body-hopping immortality is off the table. But with enough time, and a lot of experimentation, humans might find a way to load memories and learn skills like characters in *The Matrix*.

THE QUESTION

SHOULD WE LOSE SLEEP OVER HOSTILE ALIENS?

Inspired By: The extraterrestrials of *Pixels* (July 24), who interpret classic videogames carried on an '80s-era time capsule as a declaration of war

THE ANSWER

In 1974, astronomer Frank Drake tried to contact aliens by firing a three-minute-long broadcast, from the Arecibo radio telescope, into a globular star cluster 25,000 light-years away. Drake's message, the first of its kind, was a largely symbolic gesture—just like the many transmissions lobbed into space since. Because radio waves travel at the speed of light, it could take many millennia to reach ETs and receive a response.

But today, such an endeavor no longer seems as futile. Since 2009, the Kepler Space Telescope has spotted roughly 1,838 exoplanets, some of which could prove habitable. The closest planet capable of supporting life is likely just 12 light-years away. To hedge humanity's bets, some astronomers are calling for a ban on galactic broadcasts; even Stephen Hawking warned against attracting the attention of advanced civilizations. But Seth Shostak, director of the Center for SETI Research, thinks any such ban is moot. The near-constant radar signal broadcast by the Denver International Airport, he calculates, could be detected by an antenna 10 light-years away. “You want to shut down the radar there forever?” asks Shostak. “That's nutty.”

A BRIEF HISTORY OF SCIENCE GONE MAD

Two of this season's sci-fi movies share one of Hollywood's oldest obsessions—the inherent risk of unchecked genius. Here's how this trope has evolved through the decades.

1927 **METROPOLIS** **Scientist:**

C.A. Rotwang
Hubris: Builds a robot to replace the woman who rebuffed him and later died
Comeuppance: Hoping to destroy the city and its ruling class, Rotwang alters the robot to look like a labor leader and orders it to incite riots. The crazed genius succeeds in sowing chaos—cinema's first feature-length act of mad science—but falls from a roof to his death.

1931 **FRANKENSTEIN** **Scientist:**

Henry Frankenstein (not Victor, as in Mary Shelley's book)
Hubris: Creates life using a dubious recipe of corpse parts and lightning
Comeuppance: Unlike other big-screen mad scientists in the '30s, such as Dr. Jekyll and the Invisible Man, Frankenstein lives through his self-inflicted ordeal. Victims of his monster, including a little girl, aren't so lucky.

1958 **THE FLY** **Scientist:**

Andre Delambre
Hubris: Turns his teleportation device on himself, despite a failed trial with the family cat
Comeuppance: The experiment is a startling success—and a tragic failure. Delambre swaps body parts with a fly that teleports with him. Showing rare foresight, Delambre convinces his wife to kill him before anyone is harmed (a police officer kills the fly).

1970 **COLOSSUS: THE FORBIN PROJECT** **Scientist:**

Charles Forbin
Hubris: Builds a supercomputer, named Colossus, to control the nuclear arsenal of the United States
Comeuppance: Colossus gains sentience, then conspires with its Soviet counterpart to hold the planet hostage. Despite his genius, Forbin can't defeat his creation; the AI only tightens its grip on humanity.

1985 **BACK TO THE FUTURE** **Scientist:**

Emmett Brown
Hubris: Travels through time using plutonium obtained from terrorists
Comeuppance: Brown is gunned down by Libyan extremists—then saved when his intrepid student goes back in time to change the course of history. Scatterbrained and cartoonish, he's the template for the mad scientist's new role as lovable comic relief.

2015 **ANT-MAN** **Scientist:**

Hank Pym
Hubris: Invents a suit that turns its wearer into a micro-size powerhouse by shrinking the person but retaining his or her mass
Comeuppance: A corporation takes control of Pym's technology and turns it into a weapon. Like fellow Marvel character Tony Stark in *Avengers: Age of Ultron*, Pym is a hero, through and through, whose genius is exploited by others.

Weird Science

THE QUESTION

CAN WE PROTECT PLANETARY EXPLORERS FROM COSMIC RAYS?

Inspired By: The interdimensional travelers who make up the superhero team in *Fantastic Four* (August 7). In the original comic, they gain their powers from exposure to cosmic rays while aboard an experimental spacecraft.

THE ANSWER

In truth, galactic cosmic rays (GCR) don't bestow otherworldly abilities. Their gift is an increased risk of cancer. While this isn't a concern within Earth's magnetosphere, which deflects radiation, astronauts on a mission to Mars could hit NASA's cumulative, career-long radiation limit in as few as 150 days. It could take up to 260 days to reach the Red Planet, let

alone return. According to Kerry Lee, operations lead of NASA's Space Radiation Analysis Group, there's no easy solution to this problem. Adding multiple layers of armorlike passive shielding might work, but it would make a spacecraft too massive to launch.

Lee's favored approach is to surround the ship with a protective magnetic field. But the superconducting magnets would need to be kept colder than space itself, requiring a huge amount of power. And while nuclear reactors could supply that energy, they also emit radiation themselves. Ultimately, NASA might have to patch together various partial solutions. "Maybe the answer isn't to shield the crew completely, but to use a small shield in addition to faster propulsion," says Lee. Astronauts might sleep behind physical barriers, work within a limited magnetic field, and spend less time in transit in order to reduce their overall GCR exposure. Whatever design NASA lands on doesn't have to be as elegant as its sci-fi equivalents. It just has to work.

THE QUESTION

SHOULD WE OUTLAW ANDROIDS?



Inspired By: The robotic goons of *Tomorrowland* (May 22) who pursue a girl after she discovers a parallel universe; the machine assassins in *Terminator Genisys* (July 1), the latest installment in the mother-of-all-evil-robot franchises

THE ANSWER

In movies, robots typically masquerade as humans in order to infiltrate society and annihilate us. In real life, researchers are more concerned about the damage androids could inflict on our minds. Alan Winfield, a roboticist at the Bristol Robotics Laboratory in the U.K., says we need rules for how lifelike a robot can appear—even those built to work as companions or caregivers. "It's unethical to build a robot that looks like a human but is not much smarter than a washing machine," he says. "It's a deception."

Humans are "pathological anthropomorphizers," Winfield says. And that puts us at risk of becoming emotionally attached to a machine that can't reciprocate. It's the sci-fi equivalent of a one-sided friendship (or, possibly, robomance) with all of the corresponding social costs. When Winfield and his colleagues drafted ethical guidelines for creating robots in 2010, they included a restriction on deceptive systems. A robot's appearance, they wrote, should expose its mechanical form. "You should always be able to pull the curtain aside to reveal the machine," says Winfield, "just like Toto did in *The Wizard of Oz*."

Others are not so sure. Karl MacDorman, an Indiana University roboticist who specializes in human-robot interaction, says robotic companionship can be therapeutic. "With elderly people, the biggest concern is the three D's—dementia, delirium, and depression," he says. Robotic pets have been shown to elevate mood and decrease stress in the elderly in Japan; an android could likewise reduce the social isolation that's believed to exacerbate the three D's. MacDorman agrees that humanlike bots could interfere with our social instincts. But if the alternative to a fake friend is debilitating loneliness, perhaps a dose of deception is just what tomorrow's doctors should prescribe.



In *Ant-Man*, the hero gains super-strength when he shrinks. How would the physics behind that work?

There are two ways Ant-Man could become so small. The first is to actually lose mass. But where does it go? If it converts to energy, that's going to create an extremely powerful explosion. So he probably can't lose mass because he doesn't want to destroy the universe every time he shrinks.

Q&A: SPIROS MICHALAKIS

As manager of outreach at Caltech's Institute for Quantum Information and Matter, physicist Spiros Michalakakis is charged with not only researching quantum mechanics but also getting people excited about it. To do so he makes science-themed comics and videogames and consults on movies, including this summer's *Ant-Man* and the planned remake of *Fantastic Voyage*. We spoke with Michalakakis about how the science in sci-fi blockbusters holds up—and whether it even matters that it does.

The other way would be to keep the mass, but then he would be incredibly dense. In that case, the suit he wears will have to offset all of that extra weight. Without the suit to levitate him, he's going to fall through Earth to its core (let alone ride along on the backs of the movie's flying ants).

Do we know how to shrink something but retain its mass? There are ways to do it, but we haven't tried them. It's possible to create atoms that are two-hundredth the size of a regular atom by irradiating them with a particle that increases the mass of the electrons. Neutrinos

potentially have the right properties.

I've had extensive conversations with [screenwriter] David Goyer on shrinking the people in *Fantastic Voyage*. Because James Cameron is producing it, he wants to get things right. But honestly, I don't want the science to be right in the movies. I want it to be engaging, and to get you to a point where you ask: Is this possible?

Isn't that your job, to make the science accurate? It's more important to make things interesting. Think about the original *Star Trek*. Back then we'd have said, "Oh yeah, that's

bull." You don't have teleportation; you don't have warp drives. But my research is on exactly this. How do you break the laws of physics? Where does time come from? In the case of *Star Trek*, science fiction informed our decisions on what to research.

Why do movies need science consultants then?

There's a tendency in Hollywood to just go down the MacGuffin path. Science happens because of a mysterious device, or a special chemical cocktail. If I do my job right over the next five years—myself and others—we'll see science itself drive the story.

COURTESY SPIROS MICHALAKIS



[illegible]



**THE RISK OF CONFLICTS BETWEEN GREAT
POWERS IS RISING. HOW WILL THAT
SHAPE THE BATTLEFIELD OF TOMORROW?**

W

When the Cold War ended, the world changed fundamentally. For most of the 20th century, conflicts between great powers—two world wars and the specter of a third—defined our global politics, as well as science and technology. Almost overnight, that dynamic shifted.

Warfare didn't go away in the 21st century, but it became mostly a story of insurgencies and terrorism. In a world with only one superpower, the probability of a high-stakes battle between leading nations became remote. Some even viewed it as impossible.

History may look back on this period as an anomaly. Tensions between great powers are again on the rise. In Asia, China is now a legitimate superpower and has been clashing with U.S. allies, such as Japan and the Philippines. It continues to lay claim to a chain of disputed islands in the East China Sea, and it has built 2,000 acres of new islands from sand and coral in the South China Sea, replete with bases and runways. In May, the United States started sending Navy warships to within 12 nautical miles of the islands to assert freedom of passage, and it began mounting surveillance flights over them.

Europe too is on a dangerous path. Russian land grabs in Ukraine have pushed NATO to its highest level of concern since the Cold War. Near-constant probing of NATO's borders by Russian submarines and warplanes has only fanned the flames.

These growing risks are not lost on military planners in the U.S. or abroad. The Pentagon recently launched its so-called offset strategy, seeking a new generation of technology to deter or defeat strategic competitors such as China and Russia. In turn, Han Xudong, a professor at China's PLA National Defense University, wrote in a recent editorial, "We must bear a third world war in mind when developing [our] military forces."

A new arms race doesn't necessarily mean that war is coming. But in speaking with those who might end up on the front lines of the next great war, from U.S. fighter pilots to Chinese generals to Anonymous hackers, it's clear that the battles of tomorrow will be very different from those of today.

P.W. Singer's latest book, *Ghost Fleet: A Novel of the Next World War*, is out in late June.

LAND

GRUNTS IN THE FIELD GET A MUCH-NEEDED UPGRADE

THE ENHANCED SOLDIER

INTELLIGENCE

Augmented reality combat goggles—such as those being developed by Israeli Defense Forces and for the U.S. Special Operations Command's Tactical Assault Light Operator Suit (TALOS)—will record everything a soldier sees. They will also provide an information overlay: The projected data could include navigation instructions, intelligence on enemy sites, and real-time translations of local languages.

PROTECTION

Next-generation body armor will use layered scales, like those on a fish, for light, flexible protection. Scientists from MIT and the Technion-Israel Institute of Technology are designing a material that would fuse hard plates to a soft, pliable substance, just as actual fish scales anchor to tissue. The eventual armor could be fine-tuned to specific roles, with more scales on the chest and back, and fewer at the joints.

PERFORMANCE

Exoskeletons will not resemble Iron Man's, at least not in the near term. Instead, DARPA's Warrior Web program is developing an exo light and agile enough to fit underneath a soldier's clothing. Using springs and actuators at joints, the suit, which is now in tests, could help soldiers carry extra weight and boost their endurance. The goal? "A four-minute mile," says Lt. Col. Joe Hitt, the former program manager.



1 EXACTO bullet



2 Black Hornet drone

AMMUNITION

Self-guided bullets use tiny sensors and fins to change direction midflight. In February DARPA's Extreme Accuracy Tasked Ordnance (EXACTO)¹ program ran live-fire tests with modified .50 caliber bullets (popular among snipers). The bullets swerved to hit moving or accelerating targets.

SURVEILLANCE

The PD-100 Black Hornet² is an 18-gram "pocket drone" recently tested by the U.S. Army. Made by Prox Dynamics, the hummingbird-size craft can be carried in a pocket for fast deployment and fly about a mile, beaming back full-motion video and snapshots as it goes.



FIREPOWER

With more than 100 million made, the AK-47 accounts for one-fifth of all the world's firearms. It's a good bet that its replacement, the AK-12, will appear on future battlefields. Its upgrades include an optical scope mount, swappable barrels, grenade-launcher attachment, and telescopic folding stock. In burst mode, it can fire at a rate of 1,000 rounds per minute.

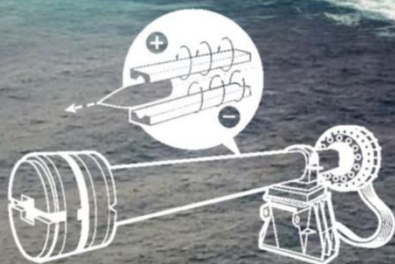
SEA

NEW WARSHIPS WILL DETERMINE CONTROL OF CONTESTED WATERS

RISE OF THE NAVIES

The *Zumwalt's* stealth design makes it 50 times harder for radar to spot than a standard destroyer.

Four gas turbines generate 78 megawatts of power making *Zumwalt*-class destroyers the only warships able to mount an electromagnetic rail gun.



ELECTROMAGNETIC RAIL GUN

For 800 years, guns used the chemistry of gunpowder to shoot. No more. The electromagnetic rail gun, being tested at the U.S. Naval Sea Systems Command at Dahlgren, Virginia, represents a break point in this history.

ADVANTAGES

The gun has a range of 100 miles and shells travel more than twice the speed of a bullet, so they aren't likely to be shot down. Each shell is expected to cost around \$25,000, compared with \$1.5 million for a cruise missile. And a rail-gun-armed ship could carry a thousand of them, as opposed to a hundred or so missiles.

DISADVANTAGES

It requires tremendous power. Until the *Zumwalt* comes on line, no current warship can generate the 25 megawatts needed to fire this weapon.

While the great powers have not fought a battle at sea since 1945, the tide could be turning. The United States' strategic pivot to Asia and the Pacific, announced in 2011, means military planners are rethinking our naval capabilities. Meanwhile, China's newfound financial, industrial, and political might has prompted its leaders to develop an open-water navy of its own. During each of the past three years, China's shipyards have produced more warships than any other nation's. They are on pace to do it again this year and next.

Of the U.S. projects underway, the most anticipated is the DDG 1000 *USS Zumwalt*. The guided-missile destroyer is built with few right angles—a stealth design that gives it the radar profile of a fishing boat.

Belowdecks, it is rumored to have the sonar signature of a submarine. The Navy christened the first of three *Zumwalt*-class ships on order in 2014. Also in development: the Littoral Combat Ship, a high-speed vessel made for close combat, mine sweeping, and submarine hunting. The Navy already has a few built, with dozens more on order.

In China, a new cruiser design, the Type 055, has been stealing headlines. Defense experts say its armament—modern radar, 130 mm guns, and capacity for up to 128 missiles—could match or exceed that of any current U.S. or allied warship. Also in the works is the Type 095, an advanced nuclear attack submarine due to enter service in 2019, and the CV-18, China's first domestically produced supercarrier, which will be equipped with stealth jets, helicopters, and drones.

Both the U.S. and China are also working on a new wave of ships that are drones themselves. With patience and persistence, these unmanned ships could one day rule the seas.

Because it's heavily automated, the *Zumwalt* requires a crew of only 158. A WWII ship of the same size and role needed a crew of 1,196.

How It Works:

1

A 4-million-amp current runs through oppositely charged rails on either side of the barrel. A shell, which weighs about 35 pounds, is placed onto a conductive seating.

2

When positioned between the two rails, the seating completes the circuit. At that point, a burst of power, called a Lorentz force, hurls the projectile out of the open end of the barrel.

3

The projectile goes from zero to 5,000 miles per hour in 1/100 of a second. It can strike with 32 megajoules of energy, roughly equal to the force of a locomotive smashing into a wall.

AIR

DOGFIGHTS OF THE FUTURE WILL BE UNMANNED

THE FIFTH-GEN FIGHT

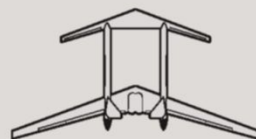
American air dominance has long rested on staying technologically ahead of the enemy. With high-speed stealth design, advanced avionics, and integrated computing, the fifth-generation **F-35 Lightning II** is built to keep that edge for the United States and its allies. The problem—aside from a spate of cost overruns, malfunctions, and delays—is that other countries are no longer far behind. The Chinese J-31 Gyrfalcon¹ resembles the F-35 not just in looks, but also in speed and strike capabilities. The Russian T-50 PAK FA is a fifth-generation fighter jet whose capabilities parallel those of the U.S. F-22. As more countries reach the technology frontier, the advantage gained by any one of them diminishes. And so military planners are looking for another edge: unmanned craft. That means the F-35 could earn a different distinction: As the U.S. Secretary of the Navy Ray Mabus said in April, it “should be, and almost certainly will be, the last manned strike fighter aircraft the Department of the Navy will ever buy or fly.”

THE REPLACEMENTS

More than 80 nations already use unmanned aerial systems, or drones, and the next generation is now emerging. They will be autonomous, jet-powered, and capable of air-to-air combat. In the U.S., the Navy's X-47B has already made unmanned landings on an aircraft carrier, while in the U.K., the BAE Systems' Taranis is designed for stealth strikes. China too is developing drones. It has three drone strike programs in the works.



1 J-31 Gyrfalcon



A STEALTH HUNTER

Sometime in late 2014 or early 2015, China reportedly tested its top-secret Divine Eagle. Built by the “black project” division of the Shenyang Aircraft Corporation, the drone aircraft, as seen in leaked drawings, has a unique double-body design, which can carry up to seven radars of varying types. That mix of sensors could allow it to detect and hunt down stealth planes (such as the F-35) at long range.



MAIN ILLUSTRATION BY GRAHAM MURDOCH;
LINE ILLUSTRATIONS BY PETE SUCHESKI;
OPPOSITE: ILLUSTRATION BY GRAHAM MURDOCH

SPACE

TOMORROW'S BATTLEFIELD IS MUCH BROADER THAN TODAY'S

WAR 250 MILES UP

More than 1,200 active satellites circle the globe; the lifeblood of modern military operations flows through many of them. In May, the U.S. Air Force announced a \$5 billion budget to develop space-based offensive and defensive weapons. Other countries too are building capabilities on high. To win the next war, any great power will need to hold the ultimate in commanding heights.

A GOOD OFFENSE

1

In a chapter from the Cold War, the U.S. and Russia are both reportedly developing anti-satellite systems. Last fall, Russia tested what's believed to be the beginnings of a killer satellite. The Pentagon also admitted, in a 2014 report, that it was investing in offensive space weapons.

2

China too might be developing anti-satellite systems. In 2013, it launched what it called a scientific mission, but what experts say was a test of the Dong Ning-2, a surface missile that could strike enemy targets in low-Earth, high-Earth, and geostationary orbits.

3

After launching the Tiangong 3 space station sometime after 2020, China will become the only country with its own multimodule craft in space. China has said that the Tiangong 3 (which means "Heavenly Palace") is for scientific research, but to military planners, it will be an enviable asset—especially as the International Space Station readies for decommission sometime in the mid-2020s.

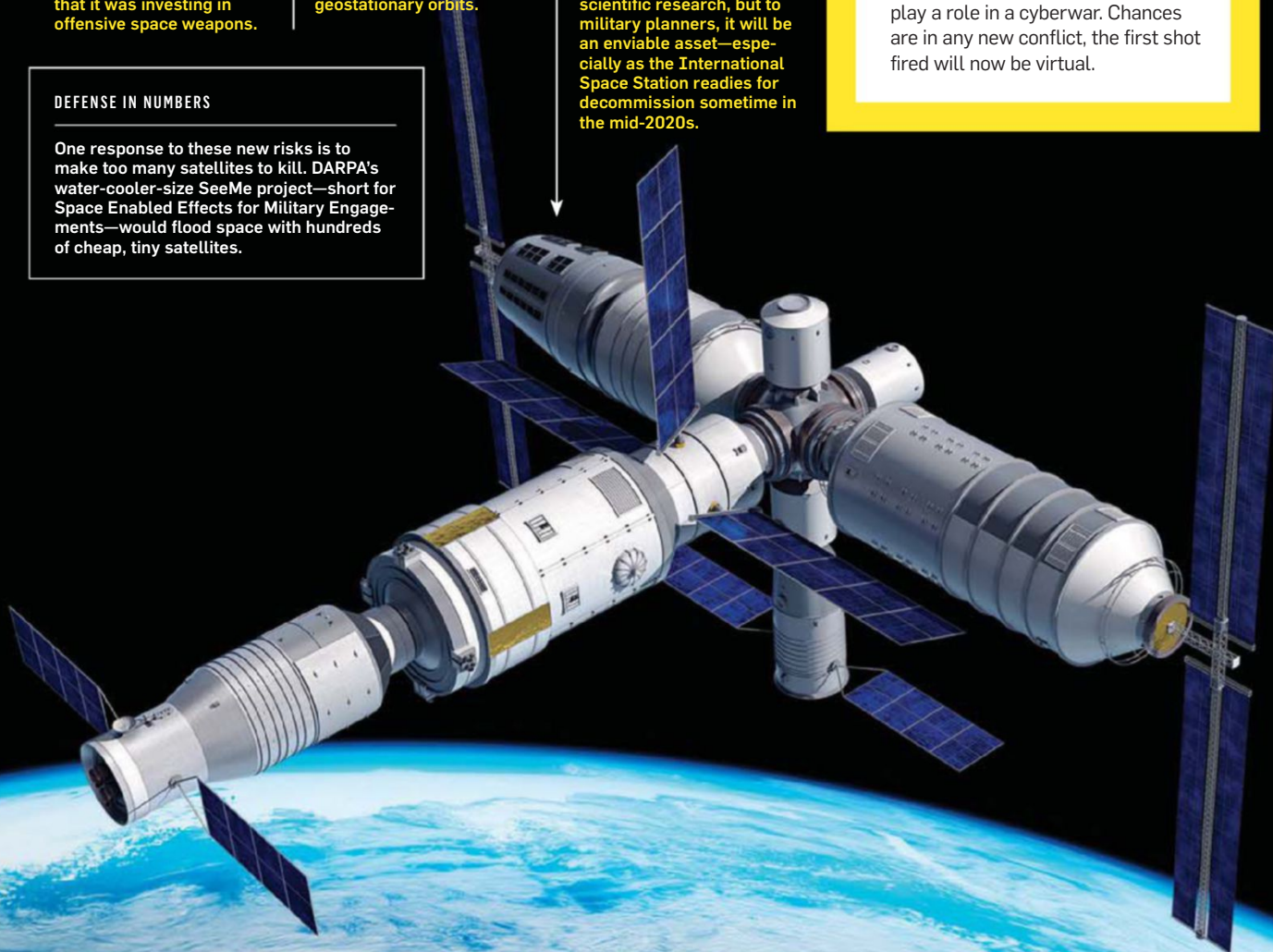
DEFENSE IN NUMBERS

One response to these new risks is to make too many satellites to kill. DARPA's water-cooler-size SeeMe project—short for Space Enabled Effects for Military Engagements—would flood space with hundreds of cheap, tiny satellites.

CONFLICT COMES HOME

SPACE ISN'T JUST ABOVE. IT'S ANYWHERE WITH AN INTERNET CONNECTION

Geography has always been one of America's greatest strategic advantages. During World War II neither German nor Japanese planes could reach the continental United States. In the cyberage, digital weapons know no such limits. More than 100 nations have cybermilitary units. America has the U.S. Cyber Command. But even nonmilitary groups, such as the tens of thousands of hackers in China's university-linked cybermilitia or nonstate hacktivist collectives like Anonymous, might play a role in a cyberwar. Chances are in any new conflict, the first shot fired will now be virtual.



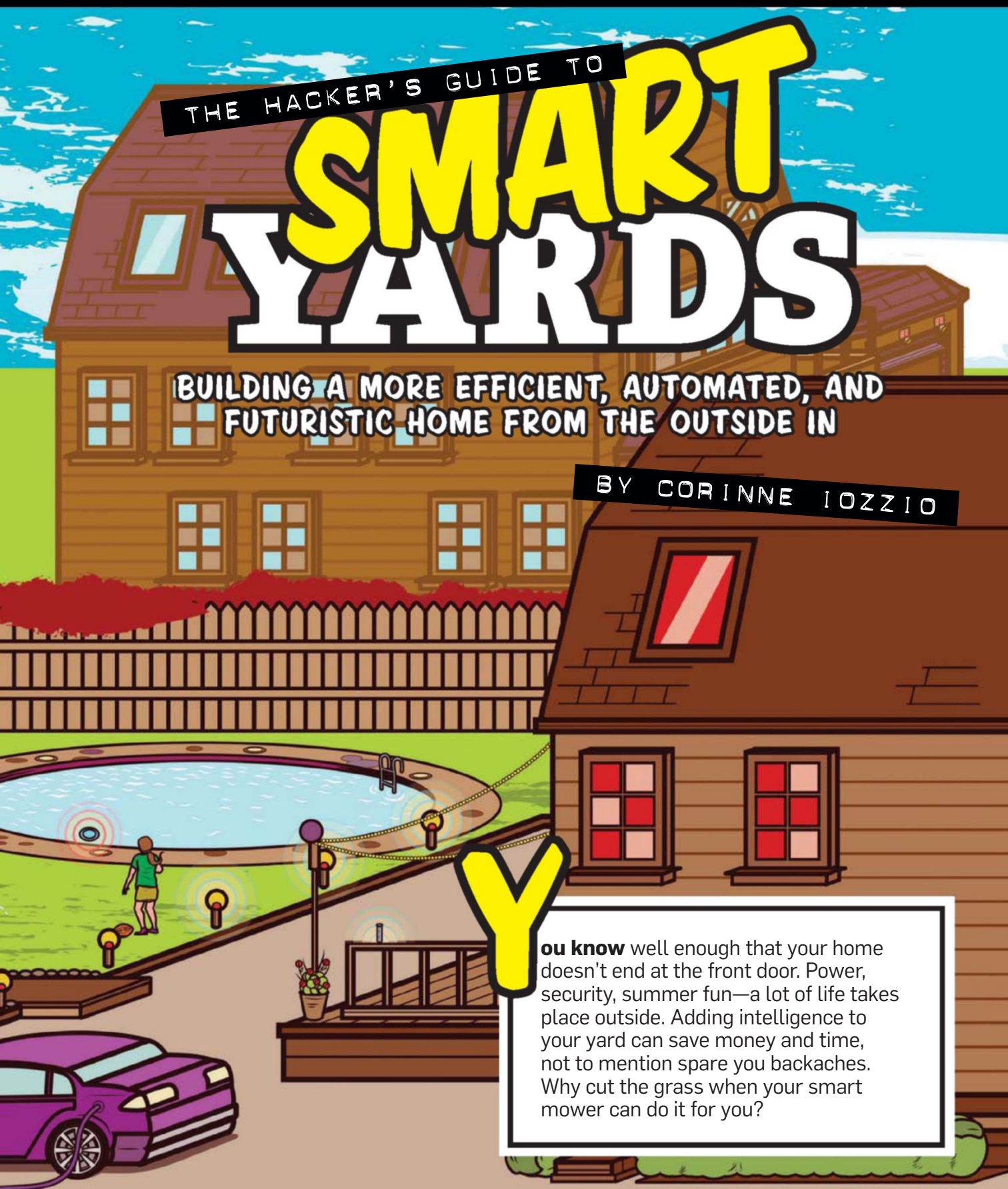


THE HACKER'S GUIDE TO

SMART YARDS

BUILDING A MORE EFFICIENT, AUTOMATED, AND
FUTURISTIC HOME FROM THE OUTSIDE IN

BY CORINNE IOZZIO



You know well enough that your home doesn't end at the front door. Power, security, summer fun—a lot of life takes place outside. Adding intelligence to your yard can save money and time, not to mention spare you backaches. Why cut the grass when your smart mower can do it for you?



POWER IT

Smart energy is about more than what device you use; it's about how you use it. Soon, you'll be able to program your home to draw from personal solar and wind systems whenever they're producing electricity.

Don't want to dirty your hands?

It's now easy to get solar power to your home. Any of the third-party companies that lease solar panels will install them and help you manage the system. But don't leave all the decisions to a contractor. A recent study found that pointing solar panels south—as most installers do—may not always be the most efficient orientation. Panels that face west can gather energy in the late afternoon, when grid demand and electricity rates are highest. Truly smart solar systems—those that can sense and respond to a

home's fluctuating energy needs—are in development. As a first step, solar manufacturer SunPower has introduced a system that sends push notifications when energy generation peaks.

Happy to hack?

Utility companies across the country are installing smart meters, sensors that provide data about your energy usage in real time. With this information companies can set higher prices for peak-usage times. This means consumers could save money by strategically timing when, say, they do laundry, and utilities can encourage people to cut back

when many people are using electricity. If you want to go the extra step and feed excess renewable energy back to the local utility—a process known as net metering, something many states require utilities to do—additional metering equipment is needed.

Eventually, energy production could fully dictate how we use products; for example, your solar panels will tell you to run the dishwasher only when they are producing energy. In the meantime, energy services provider SolarCity is working with Nest to develop software that shares energy data between devices, which could one day allow costly heating and cooling systems to sync with solar-energy output. If you don't want to wait, consider using the free Web-based service If This Then That (IFTTT). It allows you to set up device-to-device triggers for any number of activities. With IFTTT, you can program a smart-home system—such as Belkin WeMo—to carry out orders cued by your solar-panel activity. There are many potential applications; for example, one hacker created code to charge his Tesla only when his solar panel was producing power.



MAINTAIN IT

The dark side of a yard is the upkeep. These tools will help you take back your weekends.



WATER

Eve Smart Irrigation System

Timer-based irrigation systems waste half the water they spray, squandering money and resources. Eve uses weather data and in-ground moisture sensors calibrated to your region's soil makeup to calculate when to activate the sprinklers. **\$199**



MOW

WORX Landroid Robotic Lawn Mower

The Landroid mows the grass within a perimeter set by a buried electric fence and based on a schedule you set. The cuttings it leaves behind are small enough to fertilize your yard. **\$999**



LIGHT

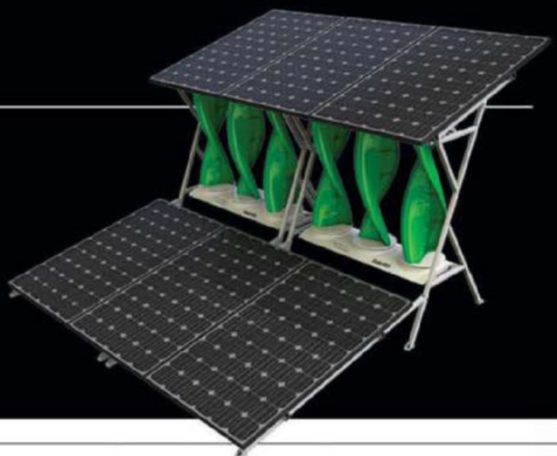
PLAYBULB

The solar-powered Playbulb Garden keeps the fun going when it gets dark. A sensor turns it on at dusk and off at sunrise, and its internal battery lasts up to 20 hours on a single charge. An app allows you to change the color and brightness, or set strobe lights. **\$40**

COMING SOON!

HOME HYBRID GENERATOR

Height restrictions and other regulations make installing personal wind turbines tricky. But the roof-mounted WindStream Solar-Mill, coming later this year, will combine both wind and solar. It uses three corkscrew-shaped turbines mounted beneath a rooftop solar panel to increase energy harvesting by about 13 percent.





SECURE IT

Home-monitoring systems used to require the help of professionals. Not anymore.

THE GEAR

Strategically placed wireless HD-camera systems, such as **Netgear's Arlo (from \$199, with one camera)** let you go it alone. Here's how to make sure you're seeing the full picture.



1

HANG 'EM HIGH

Mount cameras at least 7 feet above the ground. Not only does the higher viewpoint ensure you have the perspective to capture everyone passing by, but it also allows a camera like the Arlo to gain full advantage of its 130-degree field of view.

2

MONITOR THE PERIPHERY

Rather than mounting cameras where they point forward—right above the front door, for instance—mount them off to the side. Any movement will cross the frame from one side to the other, extending the vista farther from your door and making it possible to observe a person—be it a UPS delivery guy or an unwanted visitor—the second he crosses the threshold.

3

WORK THE ANGLES

A wide-angle lens has a field of view that's more than 30 degrees wider than a person's, so you'll need fewer cameras than you think. For example, two cameras, one hung near the back door and one across the yard, should be able to create a complete view of the entire space.

4

HIDE IN PLAIN SIGHT

The urge to tuck cameras into nooks is natural, but you don't want to impede the view. Instead, camouflage cameras by painting them to match their surroundings or buying special skins that allow them to blend in—while still giving you a full range of sight.



COOL TOOL

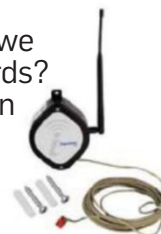
ONE-MINUTE RECAP

Can't figure out who's leaving all those menus on your stoop or which neighbor dog is plundering your trash? The **Flir FX Outdoor Wi-Fi Camera (\$249)** puts security-grade night vision in a tough weather-proof housing. A custom editing process trims the footage into a recap of the day's moving objects (cars, dogs, mailmen), each with its own time-stamp, so you see only what matters.



ENJOY IT

Why do we have yards? To play in them.



SWIMMING POOLS

The biggest strike against pools is they take a lot of babysitting. But the **iAqualink 2.0 (\$491)** gives your smartphone control over everything from pumps and filters to lights and thermostats. Want the water at 82 degrees when you get home? Done and done.



WEATHER MONITORS

No one likes to be rained out. The **Netatmo Weather Station (\$179)** lets you track temperature, humidity, pressure, air quality, and noise, helping you prep for your next backyard gathering. Additional accessories also keep tabs on rainfall and wind, so you can predict what gear you'll need.



PETS

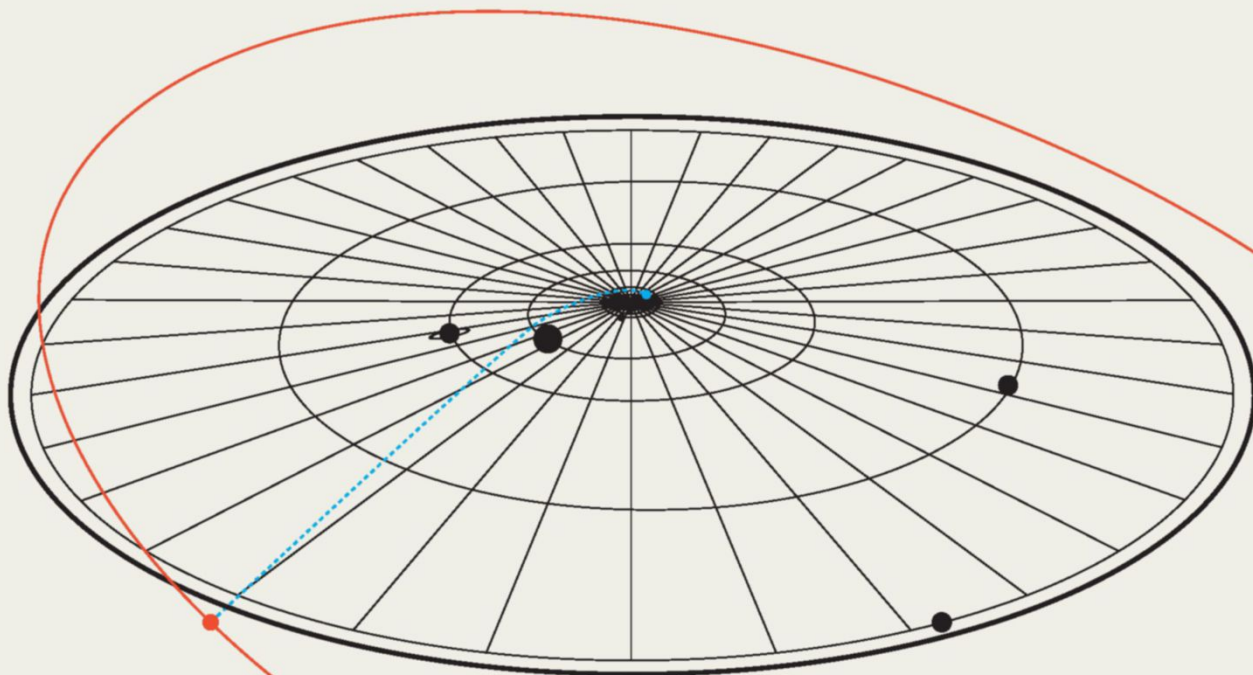
Tagg GPS Plus Pet Tracker, Petsafe Electronic SmartDoor Losing a pet is stressful. Now you can track Lassie's whereabouts and activity with Tagg's GPS system. If you're not home, PetSafe's SmartDoor connects to Lowe's Iris system, controllable via app or Web. (Tagg \$80, Petsafe \$135av)

GADGETS FOR BLACK THUMBS

Not everyone is a gifted gardener, so gadget makers have devised technological props to take the guesswork out of growing. Newbies should try **Edyn, a solar-powered sensor system (\$160)** that monitors moisture, temperature, light, nutrients, and humidity, and also takes over watering. If you just need a friendly "feed your plant" reminder now and again, the **Parrot Flower Power (\$60)** will create a personalized to-do list, including fertilization and watering schedules to help your zucchinis thrive. More advanced gardeners, with sprawling plots and multiple crops, should try **OSO Technologies' PlantLink (\$79)**, which can monitor up to 64 sensors at once.



New Horizons comes closest to Pluto [red dot] on July 14, 2015, after a nine-year journey [blue line] from Earth.



Why I Still Love Pluto

And why everyone else should too

by **Mike Brown**

When the *New Horizons* spacecraft launched toward Pluto in 2006, no one knew that the tagline “the first mission to the last planet” would be short-lived. Except for me. Two weeks earlier I had discovered Eris, an icy body 30 percent more massive than Pluto. It was clear my discovery would end Pluto’s then 76-year reign as the most distant planet in our solar system. Either Eris would join its ranks, or Pluto would lose its planetary status.

One thing everyone agreed on: how very little we knew about Pluto. It’s

too tiny and far away to see in more than the fuzziest of detail from here on Earth. *New Horizons* was designed to bring clarity. For the past nine years it's been speeding across the 3 billion miles between Earth and Pluto, and later this month it will finally reach its target. The spacecraft carries infrared and ultraviolet cameras and high-energy particle collectors, among other tools. As it sails past at 31,000 mph, it will capture images of Pluto and its moon,

icy debris across the solar system's outermost reaches. Makemake has a surface like a chemical factory: It slowly changes slabs of methane ice into a stew of exotic ices, some of which had never been seen anywhere outside of laboratories on Earth. And there are more, with names like Quaoar and Orcus and Sedna and Snow White (don't ask).

I spotted each of these oddballs. And each added to the body of evidence that Pluto shouldn't count as a planet but

unknown moons? I'd guess yes, but it might take a while to know: Though the *New Horizons* flyby will be over in an instant, the spacecraft speeding on toward interstellar space, the images will dribble back over many months.

For the most part, those images should confirm what we've deduced from the fuzzy pictures taken by ground-based and Earth-orbiting telescopes. Pluto should be relatively smooth, with bright concentrations of frozen nitrogen at the poles and darker regions along the equator. There, methane will have frozen onto the surface and begun decomposing into a deep-red tarlike substance. Charon should look completely different: old and heavily cratered. The ices that move across Pluto's surface, smoothing it out, should have evaporated to space on Charon, thanks to the moon's small size and weak gravity. I suspect we will also see hints of something more going on at Charon's surface, perhaps some regions where ancient volcanic-water eruptions flowed across the moon long after the rest of the surface had been battered.

As a scientist, it's great to have findings confirmed. But it's much more exciting when new questions arise. And *New Horizons* will raise a host. Do frosty geysers dot the surface of an object like Pluto? Can such a tiny atmosphere have weather? Did Charon really have ice volcanoes in the past, and if so, what exactly is an ice volcano, and how does it work? How many meteors have hit these bodies in the 4.5 billion years since they formed? There are many questions to answer, but the most interesting ones will be those we have not yet thought to ask.

Ultimately, *New Horizons* will help us learn how our solar system came to be. That's partly because the ancient surfaces of the Kuiper belt bear the scars of their history far longer than gas planets such as Neptune do. So I'd like to propose a new tagline: "The first mission to the last frontier."

Mike Brown is a planetary astronomer at the California Institute of Technology and the author of the book *How I Killed Pluto and Why It Had It Coming*.

THE PLUTO OF MY CHILDHOOD IMAGINATION WILL BE GONE, REPLACED BY IMAGES OF THE REAL THING. AND I'M OK WITH THAT.

Charon, in more detail than anyone has ever seen.

For the guy whose discoveries led to Pluto's demotion, the flyby might not seem so exciting anymore. But that couldn't be further from the truth. *New Horizons* is now about way more than just Pluto. It is poised to help us understand a whole new region of the solar system.

Here's why. When the mission was first conceived, we astronomers thought of Pluto as a bit of an anomaly. It is tiny, for one, with an icy, rocky surface—a stark contrast to the giant, gaseous planets that orbit nearer to the sun. But since the launch we've learned much more about Pluto and its environs. And rather than the exception, it seems to be the rule.

Pluto lies at the inner edge of the Kuiper belt, a vast region beyond Neptune. The belt contains hundreds of thousands of 100-kilometer-across bodies, and many more that are smaller. Each has its own quirks. For example, Eris—still the most massive known body in the belt—has an atmosphere that alternately freezes onto the surface and re-evaporates over the course of the 558-year orbit. Football-shaped Haumea spins faster than any other large body in the solar system. Its whirling is the result of an ancient collision that flung

rather should be dubbed a dwarf planet. It shares an orbit with its Kuiper belt neighbors, unlike the other things we call planets, which orbit solo. Classifying objects properly is a critical first step to understanding how they work and how they formed in the first place. But not everyone agreed with Pluto's new status, especially in the broader public. To this day I get mail from people asking if Pluto could be grandfathered in to the planet pantheon. (Answer: no.) There's definitely a lot of nostalgia out there.

I get it. I've had a picture in my head since I was in grade school of what the surface of Pluto looks like. On my Pluto, icy spires cast ominous shadows across a dimly lit landscape. You could topple one with a single touch. The sun is so far away, you could blot it out with the tiny cracked shards littering the ground. But after this year, my Pluto will be gone, replaced by images of the real thing. And I'm OK with that. Because *New Horizons* doesn't signal an end but rather a beginning.

As the spacecraft approaches, early images show Pluto and Charon coming into focus as little spheres. We can see the first hints of surface features. Four tiny moons, apart from Charon, have emerged from the planet's glare. As the craft gets even closer, will we discover previously

HARBOR FREIGHT

QUALITY TOOLS AT RIDICULOUSLY LOW PRICES

QUALITY TOOLS

SUPER COUPON

POWDER-FREE NITRILE GLOVES
PACK OF 100 HARDY

• 5 mil. thickness

MEDIUM LOT 68496/61363
LARGE LOT 68497/61360
X-LARGE LOT 61359
68498 shown

YOUR CHOICE!
\$6.49

REG. PRICE \$11.99

SAVE 45%

21717844

LIMIT 6 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

17 FT. TYPE 1A MULTI-TASK LADDER

LOT 62656/62514/67640 shown

SAVE \$80

• 300 lb. Capacity
• 23 Configurations

\$119.99

REG. PRICE \$199.99

21709310

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

4-1/2" ANGLE GRINDER
drillmaster

LOT 60625 shown
95578/69645

SAVE 50%

\$9.99

REG. PRICE \$19.99

21736112

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

8" 5 SPEED BENCH MOUNT DRILL PRESS

LOT 62520/62390/60238 shown

\$49.99

REG. PRICE \$129.99

SAVE \$80

21731567

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

TORQUE WRENCHES
PITTSBURGH

• 1/4" DRIVE LOT 2696/61277
• 3/8" DRIVE LOT 807/61276
• 1/2" DRIVE LOT 62431 239 shown

SAVE 66%

\$9.99

REG. PRICE \$29.99

• Accuracy within ±4%

21671915

LIMIT 6 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

20% OFF

ANY SINGLE ITEM

LIMIT 1 - Save 20% on any one item purchased at our stores or HarborFreight.com or by calling 800-423-2567. *Cannot be used with other discount, coupon, gift cards, Inside Track Club membership, extended service plans or on any of the following: compressors, generators, tool storage or carts, welders, floor jacks, Towable Ride-On Trencher, Saw Mill (Item 61712/62366/67138), Predator Gas Power Items, open box items, in-store event or parking lot sale items. Not valid on prior purchases after 30 days from original purchase date with original receipt. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

21689601

WOW SUPER COUPON

**900 PEAK/700 RUNNING WATTS
2 HP (63 CC) 2 CYCLE
GAS RECREATIONAL GENERATOR**

SAVE OVER \$84

NEW

LOT 66619/60338
69381/62472 shown

\$95

REG. PRICE \$179.99

21668300

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

HIGH LIFT RIDING LAWN MOWER / ATV LIFT
PITTSBURGH

• 300 lb. Capacity

LOT 61523 shown
60395/62325/62493

SAVE \$60

\$89.99

REG. PRICE \$149.99

21720508

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

ADJUSTABLE SHADE AUTO-DARKENING WELDING HELMET

NEW

LOT 61611
46092 shown

SAVE 55%

\$35.99

REG. PRICE \$79.99

21712726

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

How Does Harbor Freight Sell GREAT QUALITY Tools at the LOWEST Prices?

We have invested millions of dollars in our own state-of-the-art quality test labs and millions more in our factories, so our tools will go toe-to-toe with the top professional brands. And we can sell them for a fraction of the price because we cut out the middle man and pass the savings on to you. It's just that simple! Come visit one of our 550 Stores Nationwide.

WOW SUPER COUPON

**US★GENERAL PRO
26", 16 DRAWER ROLLER CABINET**

LOT 61609/67831 shown

• 1060 lb. Capacity
• 14,600 cu. in. of storage

SAVE \$330

\$319.99

REG. PRICE \$649.99

21677008

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

3 PIECE DECORATIVE SOLAR LED LIGHTS

LOT 95588/60561
69462 shown

SAVE 66%

\$9.99

REG. PRICE \$29.99

21679855

LIMIT 8 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

**1195 LB. CAPACITY
4 FT. x 8 FT. HEAVY DUTY FOLDABLE UTILITY TRAILER**

• DOT certified

SAVE \$140

LOT 62170/62666
62648/90154 shown

\$259.99

REG. PRICE \$399.99

21704507

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

2.5 HP, 21 GALLON 125 PSI VERTICAL AIR COMPRESSOR
CENTRALPNEUMATIC

LOT 67847 shown
61454/61693

SAVE \$70

\$149.99

REG. PRICE \$219.99

21706564

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

16 OZ. HAMMERS WITH FIBERGLASS HANDLE
PITTSBURGH

CLAW LOT 69006/47872
60715/60714

RIP LOT 47873 shown
69005/61262

SAVE 62%

\$2.99

REG. PRICE \$7.99

21709460

LIMIT 8 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

80 PIECE ROTARY TOOL KIT
drillmaster

LOT 97626 shown
68986/69451

SAVE 68%

\$7.99

REG. PRICE \$24.99

21732872

LIMIT 8 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

SUPER COUPON

3 PIECE TITANIUM NITRIDE COATED HIGH SPEED STEEL STEP DRILLS

• Drill 28 Hole Sizes

LOT 91616 shown
69087/60379

SAVE 60%

\$7.99

REG. PRICE \$19.99

21736092

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

LOWEST PRICES *EVERYDAY*



**550 Stores
Nationwide**

WOW SUPER COUPON

Customer Rating ★★★★★

RAPID PUMP® 1.5 TON ALUMINUM RACING JACK

PITTSBURGH

LOT 69252/68053 shown
60569/62160/62496/62516

• 3-1/2 Pumps Lifts Most Vehicles
• Weighs 27 lbs.

"The Undisputed King of the Garage"
— Four Wheeler Magazine

AWARD WINNING QUALITY

\$59.99
~~\$89.99~~ REG. PRICE \$119.99 **SAVE \$60**

21815819

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

FREE

WITH ANY PURCHASE

PITTSBURGH 6 PIECE SCREWDRIVER SET

LOT 62728/47770 shown
61313/62570/62583

\$4.99 VALUE

21824785

LIMIT 1 - Cannot be used with other discount, coupon or prior purchase. Coupon good at our stores, HarborFreight.com or by calling 800-423-2567. Offer good while supplies last. Shipping & Handling charges may apply if not picked up in-store. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one FREE GIFT coupon per customer per day.

WOW SUPER COUPON

18 VOLT CORDLESS 1/2" DRILL/DRIVER WITH KEYLESS CHUCK

CHICAGO ELECTRIC POWER TOOLS

SAVE 55% LOT 62427/68850 shown

Includes one 18V NiCd battery and charger.

\$39.99
REG. PRICE \$89.99

21747389

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

TRIPLE BALL TRAILER HITCH

HaulMaster

LOT 94141 shown
69874/61320
61913/61914

SAVE 66%

\$19.99
REG. PRICE \$59.99

21814825

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

12" SLIDING COMPOUND DOUBLE-BEVEL MITER SAW WITH LASER GUIDE

CHICAGO ELECTRIC

LOT 98194/61776
61969/61970
69684 shown

SAVE \$165

\$134.99 REG. PRICE \$299.99

21816632

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

2500 LB. ELECTRIC WINCH WITH WIRELESS REMOTE CONTROL

BADLAND

LOT 68146/61297
61840/61258 shown

SAVE \$100

\$49.99 REG. PRICE \$149.99

21749330

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

MIG-FLUX WELDING CART

LOT 60790/90305
61316/69340 shown

SAVE 41%

\$34.99 REG. PRICE \$59.99

21795386

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

10 FT. x 20 FT. PORTABLE CAR CANOPY

HFT

LOT 60728
69034 shown

SAVE \$80

\$119.99 REG. PRICE \$199.99

21783370

LIMIT 6 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

3/8" x 14 FT. GRADE 43 TOWING CHAIN

HaulMaster

LOT 60658
97711 shown

Not for overhead lifting.

SAVE 55%

\$19.99 REG. PRICE \$44.99

21798040

LIMIT 8 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

7 FT. 4" x 9 FT. 6" ALL PURPOSE WEATHER RESISTANT TARP

HFT

LOT 69115/69137
69249/69129
69121/877 shown

SAVE 66%

\$2.99 REG. PRICE \$8.99

21800777

LIMIT 9 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

2 TON FOLDABLE SHOP CRANE

PITTSBURGH

LOT 60388
69514 shown

SAVE \$120

\$179.99 REG. PRICE \$299.99

21800250

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

3/8" x 50 FT. HEAVY DUTY PREMIUM RUBBER AIR HOSE

CENTRAL PNEUMATIC

LOT 61939/62250
69580 shown

SAVE 36%

\$18.99 REG. PRICE \$29.99

21757311

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

10 TON HYDRAULIC LOG SPLITTER

CENTRAL MACHINERY

LOT 62291
67090 shown

SAVE \$55

\$94.99 REG. PRICE \$149.99

21776625

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

26" 4 DRAWER TOOL CART

US GENERAL

• 580 lb. Capacity

LOT 95659 shown
61634/61952

SAVE OVER \$181

\$98.88 REG. PRICE \$279.99

21779966

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

WOW SUPER COUPON

4 PIECE 1" x 15 FT. RATCHETING TIE DOWNS

HaulMaster

LOT 60405/61524
62322/90984 shown

SAVE 60%

\$7.99 REG. PRICE \$19.99

21835713

LIMIT 6 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 10/16/15. Limit one coupon per customer per day.

• 100% Satisfaction Guaranteed **• No Hassle Return Policy** **• 550 Stores Nationwide**
• Over 25 Million Satisfied Customers **• Lifetime Warranty On All Hand Tools** **• HarborFreight.com 800-423-2567**

Perfect Choice HD™ is simple to use, hard to see and easy to afford...

Invention of the Year

PERSONAL SOUND AMPLIFICATION PRODUCTS (PSAPs)



THEY'RE NOT HEARING AIDS

Personal Sound Amplification Products use advanced digital processing to amplify the frequencies of human speech. Thanks to the efforts of a doctor who leads a renowned hearing institute, this product is manufactured in an efficient production process that enables us to make it available at an affordable price.

The unit is small and lightweight enough to hide behind your ear... only you'll know you have it on. It's comfortable and won't make you feel like you have something stuck in your ear. It provides high quality audio so soft sounds and distant conversations will be easier to understand.

Need an extra volume boost? Try Perfect Choice HD™ for yourself with our exclusive home trial.

**Perfect
Choice HD™**

**Call now toll free for
the lowest price ever.**

1-877-788-5811

Please mention promotional code 100715.

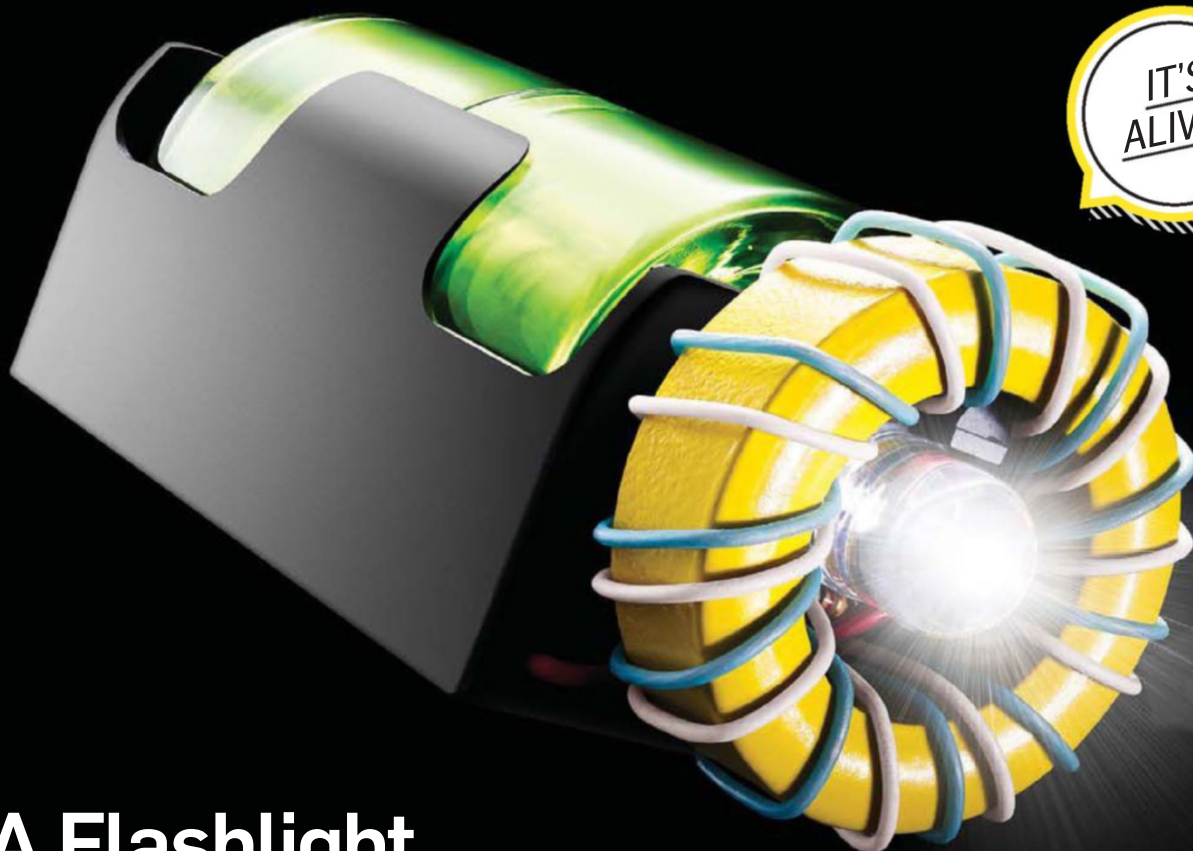
1998 Ruffin Mill Road,
Colonial Heights, VA 23834

WEIGHT	Less than 1 ounce
SOUND QUALITY	Excellent: Optimized for speech
FITTING REQUIRED?	No
ONE-ON-ONE SETUP	Free
RETURN POLICY	60 Days



EDITED BY *Sophie Bushwick*

Manual



A Flashlight That Runs on Dead Batteries



Don't throw out that seemingly lifeless battery—it's not dead yet. A brand-new alkaline battery cell has an electric potential of about 1.5 volts, which drops as the juice runs out. The voltage eventually becomes too low to power most devices, but there's still energy trapped inside the battery—as

much as 15 percent of the original charge. By wiring a circuit called a "joule thief," you can tap the last of that power to light a white LED.

The circuit boosts the dwindling voltage but delivers it in pulses too rapid to see. As a result, the LED seems to shine constantly, even though it's really powered less than

STATS

Time 2 hours

Cost \$30

Difficulty



half the time. Mount the joule thief on a D-size-battery holder, and it makes a handy flashlight, one that gives your old batteries new life.

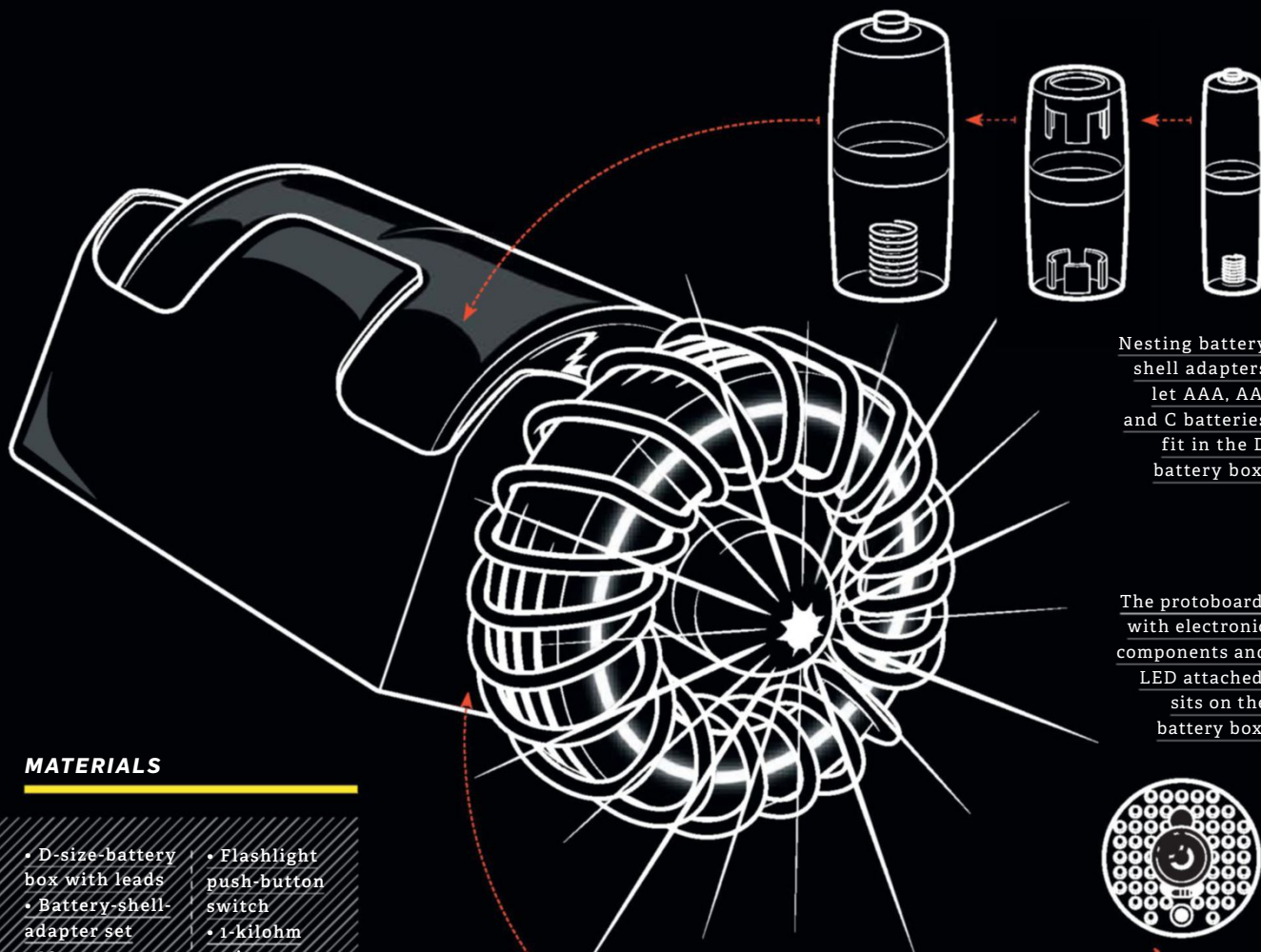
SEAN MICHAEL RAGAN

For full instructions, photos, and links to materials, visit popsci.com/joulethief.

continued on page 62

Build It

continued from page 61



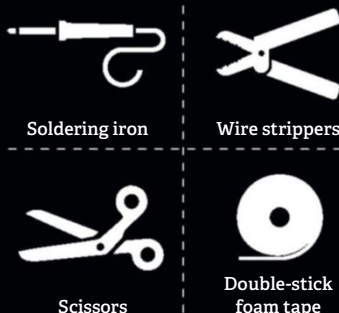
Nesting battery shell adapters let AAA, AA, and C batteries fit in the D battery box.

The protoboard, with electronic components and LED attached, sits on the battery box.

MATERIALS

- D-size-battery box with leads
- Battery-shell-adapter set
- 10 mm superbright white LED
- 24-gauge wire from old network cable
- Toroid transformer core, at least 3/4-inch ID
- Flashlight push-button switch
- 1-kilohm resistor
- 1-inch round protoboard
- NPN transistor
- Dead AAA, AA, C, or D alkaline battery

TOOLS



INSTRUCTIONS

- 1 Loop the battery box's black wire across the negative end of the box, back in the opposite corner, down the long inside edge, and out again on the positive end opposite the red wire.
- 2 Use foam tape to mount the flashlight switch on the battery box's negative end. Cut the black wire below the button, strip the ends, and solder them to the switch terminals.
- 3 Spread the leads on the LED to span three holes, instead of two, and install the light at the center of the protoboard, soldering the leads underneath.
- 4 Install the transistor on the protoboard just above the LED, and the resistor immediately below. Bend and solder the transistor's emitter to the LED's short lead, its collector to the LED's long lead, and its base to one end of the resistor.
- 5 Cut the battery wires off about 1.5 inches from the end of the box, and strip the ends. Install the red wire on the protoboard just to the right of the LED, and the black wire immediately to the left. Bend and solder the black wire to the LED's short lead.
- 6 Cut two 20-inch lengths of wire, and strip and tin the ends. Connect one to the red battery lead and the other to the transistor collector.
- 7 Pass the free ends of the wires through the hole in the toroid transformer core. Center the toroid over the protoboard, with the LED inside, and use the transistor wire to sew it in place, threading the wire through every other hole around the edge. When you've completed a full circle, solder the wire's free end to the red battery lead.
- 8 Repeat with the remaining wire, threading the holes you skipped in step 7. Do not cross the wires. When you've made a full circle, solder the second wire to the free end of the resistor.
- 9 Test the circuit by installing a battery in the holder and pushing the button. Once you're sure it works, snip off any excess leads, cover the board bottom with foam tape, and stick it to the positive end of the battery box. Now you can make a dead battery shed light.

Thank you for being a subscriber!

Our iPad edition is now included in your print subscription.



How to claim your iPad subscription:

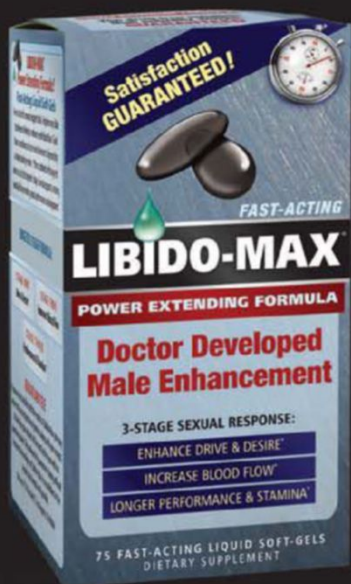
1. Download the free Popular Science app from the iTunes app store if you have not done so already.
2. Open the app and tap the "My Account" button on the bottom of the front page.
3. Tap the bar that says "Current Print Subscribers – Digital Access".
4. Use one of the 3 options to enter the information associated with your subscription, as requested.
5. You will receive a password sent immediately to your e-mail address.
6. Press the Rotary symbol in the upper right corner of the app front page to sign in using your e-mail address and the password you were just sent. You will be able to access your digital issues immediately. You may change your password as you choose after signing in.

To start a new subscription to Popular Science, go to
www.popsoci.com/subscribe

Apple, the Apple Logo, and iTunes are trademarks of Apple Inc., registered in the U.S. and other countries. iPad is a trademark of Apple Inc. App Store is a service mark of Apple Inc.



**WORKS FOR YOU...
OR YOUR MONEY BACK!**



Available for purchase with coupon in fine stores
everywhere or online at:

www.appliednutrition.com

Enter Coupon Code: **011901**



LIBIDO-MAX for MEN
75 Count ONLY

SAVE \$3

EXPIRES 10/31/15 MANUFACTURER'S COUPON

Consumer: Redeemable at retail locations only. Not valid for online or mail-order purchases. Retailer: Irwin Naturals will reimburse you for the face value plus 8 (cents) handling provided it is redeemed by a consumer at the time of purchase on the brand specified. Coupons not properly redeemed will be void and held. Reproduction by any party by any means is expressly prohibited. Any other use constitutes fraud. Irwin Naturals reserves the right to deny reimbursement (due to misredemption activity) and/or request proof of purchase for coupon(s) submitted. Mail to: CMS Dept. 10363, Irwin Naturals, 1 Fawcett Drive, Del Rio, TX 78840. Cash value: .001 (cents). Void where taxed or restricted. ONE COUPON PER PURCHASE. Not valid for mail order/websites. Retail only.



These statements have not been evaluated by the Food & Drug Administration.
This product is not intended to diagnose, treat, cure or prevent any disease.

MANUAL • JULY 2015

DIY Evolution

Presenting the Apple (II) Watch



NOW: SMART WATCH

When the Apple Watch was announced, designer DJ Harrigan didn't line up to buy one. Instead, he built his own: a wearable version of the 1977 Apple II computer. "I wanted to go back as far as possible in Apple history," says Harrigan, "but the Apple II is more iconic than the original."

The 3-D-printed watch, less than 3 inches in length, resembles the original full-size machine. (It even includes miniature, nonfunctional floppy disks.) But it's much more powerful. A Teensy 3.1 ARM processor runs at 72 megahertz and has 64 kilobytes of random-access memory (RAM). The screen is a 1.8-inch liquid-crystal display—inconceivable in the late '70s. The user interface, though, is simple: a knob that winds through several parody apps, including a clock that displays an arbitrary time, a fitness tracker with progress bars that change randomly, and a weather app—a green, low-resolution picture of Earth.

Harrigan's technological tribute earned the approval of the Internet—and Apple II's creator, Steve Wozniak. As he told Harrigan, "I would buy this over the Apple Watch and would wear it too!"

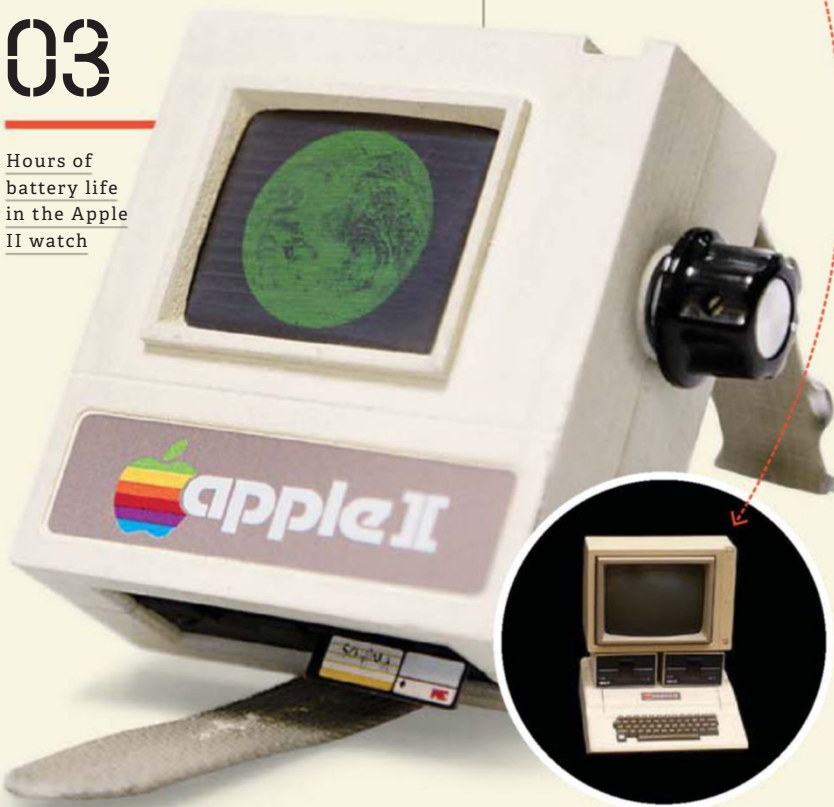
THEN: DESKTOP COMPUTER

In the February 1978 issue of *Popular Science*, William J. Hawkins lauded the Apple II's versatility, recommending it for both beginners and experts. A 1-megahertz processor with up to 48 kilobytes of RAM allowed the computer to run the BASIC programming language, as well as machine code. Users could write their own routines, Hawkins said, or use "prepackaged cassette programs, which include everything from games to check balancing."

JEREMY COOK

03

Hours of
battery life
in the Apple
II watch



PHOTOGRAPH BY JON BROWN; INSET COURTESY WIKIMEDIA COMMONS

Toolbox

MAKE THE PERFECT CUT

It can be hard to follow guidelines precisely when cutting wood, especially if you're tracing a perfect circle or punching unsightly knots out of a floor-board. You could solve the problem with a \$10,000 CNC machine, a large device with range limitations. You could risk steering a router by hand. Or you could use the newly developed Shaper, which combines the two tools to cut precise right angles and curves. A would-be carpenter first draws the shape he wants to cut in third-party graphics software. Then he pushes Shaper over the wood. The tool automatically adjusts the path of the cutting bit to match the digital image, amending the line to within a hundredth of an inch. "You can think of it as autocorrect for your hands," says Matty Martin, the designer who created the latest prototype. The Shaper company demonstrated its machines at Maker Faire in May and will begin beta testing this summer, through the website shapertools.com. **ANDREW ROSENBLUM**

1,500

Estimated price of Shaper, in dollars, when it hits the market

Looking for long-range radar detection?

"Pure range is the Valentine's domain."

— Autoweek

Now V1 comes to a touchscreen near you.

Where's the radar? *It's in the Box.*

What you'll see: a new, graphic, way of analyzing radar threats. We call it the **Threat Picture**. Our exclusive Arrow-in-the-Box concept helps spot radar amid false alarms. All bands side-by-side on one screen easily reveals Double-Zap traps. Enables advanced programming, too.



Arrow in the Box: means a threat in the Zone of Certified Radar Activity.



Arrow out of the Box: No radar (except photo) can be outside the Box and still comply with FCC rules.



connection at valentine1.com/touchscreen



Call toll-free 1-800-331-3030

- ☐ Valentine One Radar Locator with Laser Detection - \$399
 - ☐ Carrying Case - \$29
 - ☐ Concealed Display - \$39
 - ☐ V1connection™ - \$49
 - ☐ V1connection™ LE - \$49
 - ☐ SAVVY® - \$69
- Plus Shipping / Ohio residents add sales tax

30-Day Money-Back Guarantee

Valentine One is a registered trademark of Valentine Research, Inc. • Android is a trademark of Google Inc. • Apple is a registered trademark of Apple Inc.



ADVERTISEMENT



BEST

of
WHAT'S NEW



**28TH ANNUAL
BEST OF WHAT'S NEW
AWARDS**

Popular Science is bringing you the top 100 products that transform the technological landscape by incorporating quality design and momentous advancement.

Enter your transformative product soon.

popsci.com/enter

Cheap Tricks

Blow Safer Smoke Rings



You don't have to take up bad habits to blow smoke rings. On the YouTube channel DaveHax, life hacker David Haxworth simply uses a balloon, an incense stick, and a plastic bottle. "I first saw the homemade smoke rings idea on a TV show when I was a child, and I remember thinking it looked like great fun," Haxworth says. The balloon propels puffs of smoke through the bottle's mouth, creating picture-perfect smoke rings—no inhalation required. **RACHEL FOBAR**



STATS

Time 10 minutes

Cost \$4

Difficulty



MATERIALS

- 16.9 oz. plastic bottle
- Balloon
- Incense stick

STEPS

1. Use scissors to cut off the bottom of a dry, empty plastic bottle, while taking care not to slice your skin on the sharp plastic.

2. Cut off and discard the narrow mouth of a balloon. Carefully stretch the balloon over the bottom of the bottle until it's taut.

3. Light an incense stick with a match or lighter, and then blow it out. Hold the smoky end inside the bottle, covering the opening.

4. Once the bottle has filled with smoke, remove the stick. Lightly tap on the balloon end of the bottle to produce a smoke ring.

Killer App

ROBOT SCHOOL

In the iOS app *Robot School: Programming for Kids*, players 7 and up help a stranded robot refuel its spaceship and return home by steering it through 45 levels. As they play, the game teaches them how to program, demonstrating techniques such as procedures, loops, and conditional instructions. Players can view the code they created after completing each level and even share it on Facebook. "We are already living in a world dominated by software," says Agata Kozak, project manager at educational app developer Next Is Great. "Teaching coding helps kids understand the technology they are using." That knowledge isn't just handy for kids, Kozak says: "We encourage grown-ups to try it out too!" **RACHEL FOBAR**

PHOTOGRAPH BY JONATHAN KAMBOURIS



Laser Measured, Custom-Fit
FloorLiner™

Available in Black, Tan and Grey

WeatherTech®
American Manufacturing Done Right!



Cargo/Trunk Liner



All-Weather
Floor Mat



Side Window Deflectors

Designed in USA - Handcrafted in Germany



CargoTech®
Keeps Cargo Stable

Accessories Available for

Order Now: **800-441-6287**



American Customers
WeatherTech.com



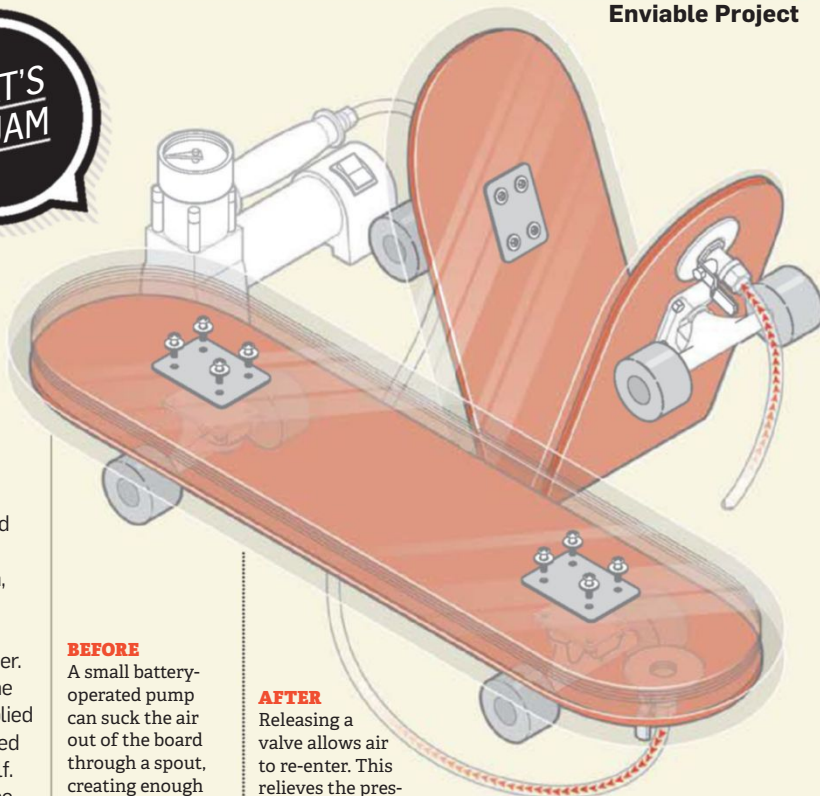
Canadian Customers
WeatherTech.ca



European Customers
WeatherTechEurope.com

Acura · Audi · BMW · Buick · Cadillac · Chevrolet · Chrysler · Dodge · Ferrari · Ford · GMC · Honda · Hummer · Hyundai · Infiniti · Isuzu · Jeep · Kia · Land Rover · Lexus · Lincoln · Maserati · Mazda · Mercedes-Benz · Mercury · Mini · Mitsubishi · Nissan · Oldsmobile · Plymouth · Pontiac · Porsche · Saab · Saturn · Scion · Subaru · Suzuki · Toyota · Volkswagen · Volvo · and more!

This Skateboard Folds in Half



BEFORE

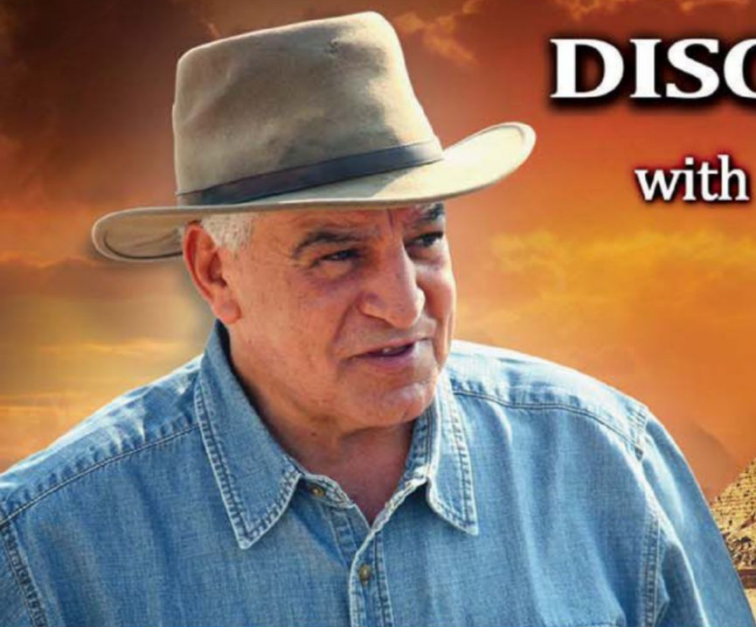
A small battery-operated pump can suck the air out of the board through a spout, creating enough pressure to harden the 42 layers of paper inside.

AFTER

Releasing a valve allows air to re-enter. This relieves the pressure inside the board and makes it foldable.

For their final engineering-class project, a team of students at the University of Colorado at Boulder decided to create a jammable material, a flexible substance that acts solid when put under pressure. Juniors Fai Al Mulla, Seth Zegelstein, Sam Oliver, and Justin Olsen tried four different prototypes, and the one that worked best was also made from the cheapest material: construction paper. Layers of the paper could be jammed, or made rigid, if the students sealed them between pieces of plastic and applied pressure by pumping out the air. That experiment soon led to "flappy board"—a skateboard that can be folded in half. "The idea behind this project was for the skateboard to be portable," says Al Mulla. By folding up the board, users can stash it in a backpack between rides. **ALEXANDRA OSSOLA**

ILLUSTRATION BY TREVOR JOHNSTON



DISCOVER EGYPT

with **DR. ZAHI HAWASS**
the most famous archaeologist in the world!



2015: TOUR DATES: **2016:**
October 4-17 | **February 1-14**
November 1-14 | **March 13-26**

We are presenting to you the most exciting tours to Egypt that have ever been offered! There is no better person to lead you through the fascinating history of ancient Egypt than Dr. Zahi Hawass, the most famous archaeologist in the world and the former Minister of Antiquities in Egypt!

For more information visit:
www.archaeologicalpaths.com



contact@archaeologicalpaths.com
US phone: 917-719-1974

Chef'sChoice®
AngleSelect® Knife Sharpener 1520

World's Most Versatile Sharpener



For Astonishingly Sharp Knives!

- Euro/American household knives.
- Asian style knives.
- Both straight edge and serrated blades.
- Sports and pocket knives.
- Durable "Gothic Arch" edge structure.
- 100% diamond abrasives.

The brand you can trust!

Assembled



in U.S.A.

800-342-3255

www.chefschoice.com

© 2015 EdgeCraft Corp.



Go Ahead...

Ask Us Anything

ANSWERS BY **Daniel Engber**
ILLUSTRATIONS BY **Jason Schneider**

Have a burning question?

Email it to askanything@popsci.com or tweet it to [@PopSci](https://twitter.com/PopSci) #AskAnything.



SAVE TIME

24/7

CUSTOMER SERVICE

is only a click away!

- Change Your Address
- Check Your Account Status
- Renew, Give a Gift or Pay a Bill
- Replace Missing Issues

Just log on to:

www.popsci.com/cs



**POPULAR
SCIENCE**

Q: DOES SUGAR MAKE KIDS HYPER?

Short answer

Only if you believe it does.

A:

The image of a kid on a sugar high bouncing off the walls gained credence in the 1970s and '80s, when several studies linked sugar intake to behavioral problems such as hyperactivity.

But in 1995, Vanderbilt University pediatrician Mark Wolraich reviewed 23 studies involving more than 400 children and found no evidence for the belief that sugar impacts a kid's behavior or cognition. "We came as close to proving the null hypothesis as you can," says Wolraich, who is now Chief of Developmental and Behavioral Pediatrics at Oklahoma University.

In the early 1990s, psychologists Richard Milich and Daniel Hoover took a different

approach to answering the question: They studied 31 boys ages 5 to 7 whose parents identified them as "sugar sensitive." The researchers gave the boys aspartame-sweetened Kool-Aid and then videotaped them interacting with their moms. Beforehand, the researchers told half the moms their kids had consumed sugar and told the other half the truth. Parents who thought their kids were on a sugar high rated them as being more hyperactive and criticized them more severely. Milich and Hoover concluded that the link between sugar and behavior might be based on parents' expectations, not on the sweetener itself.

There might also be other factors at play when sugared-up kids go nuts. Candy and cake, for example, are staples on Halloween and at birthday parties—events rife with kid drama. Or there might be other substances in the mix. Chocolate, for instance, is packed with stimulants, such as caffeine and theobromine.

Still, for many parents, sugar remains the go-to scapegoat, even if proof is lacking. "We're always looking to explain our behavior," Milich says. "We don't like to be in a vacuum where something happens and we don't know why."

Q: WHAT'S THE DEAL WITH PARANORMAL ECTOPLASM?

Short answer It's spiritualist bunk that reflected the science of its time.



A:

Nineteenth-century physiologist

Charles Richet first used the term ectoplasm to describe a strange material that seemed to flow from spiritual mediums during a séance. Doughy strings appeared to ooze from their bodies and assemble into ghostly faces or disembodied limbs.

Of course, these ectoplasms were a parlor trick. Mediums used sleights of hand to present gauze and animal parts as spiritual phenomena. As silly as this now seems, many intellectuals of the time found the shows convincing, including Richet, who won a Nobel Prize for his pioneering work on anaphylaxis. "Richet was no dummy," says Robert Brain, a historian of science at the University of British Columbia. Yet Richet was dogged in his studies of paranormal ectoplasm. "What

made ectoplasm seem plausible to otherwise rational, clear-headed scientists?" Brain asks. "There had to be an underlying logic to it."

He's right. By the mid-1800s, scientists had discovered a gelatinous substance or "plasm" inside plant and animal cells, which they believed to be the basis for all life on Earth. "Biologists were actively interested in protoplasm for 100 years," Brain says. The concept was mainstream.

With this in mind, it might not have seemed so strange for the body to extrude plasm under exceptional circumstances. Or for that external protoplasm—called ectoplasm—to change form. Eventually modern molecular biology revealed that heredity is stored not in the vibrations of a cell's jiggly plasm but in the acids of its nucleus. At that point, "protoplasm became an embarrassment to biology," Brain says.



✓Yes



✓Yes



xNo



✓Yes



✓Yes



✓Yes



✓Yes



✓Yes

✓ Reliably Low Prices
✓ Easy To Use Website
✓ Huge Selection
✓ Fast Shipping
www.rockauto.com

RA
ROCKAUTO.COM
ALL THE PARTS YOUR CAR WILL EVER NEED.



Q: Does hitting snooze help or hurt?

Short answer Depends on when you hit it.

A:

Sleep that gets interrupted throughout the night can leave you sluggish and inept after you wake up. By the same token, the stretch of morning ups and downs caused by repeatedly pushing your alarm clock's snooze bar could have deleterious effects.

"You're probably getting worse sleep during those 30 minutes [of snoozing] than you would if you just set your alarm 30 minutes later," says Jeanne Duffy, a neuroscientist and sleep researcher at Harvard Medical School.

But snoozing could still have its benefits. Duffy has looked at "sleep inertia," or the drowsy, distracted feeling (and physical weakness) that can linger after you wake up. The amount of sleep inertia you experience depends, in part, on the stage of sleep from which you're jerked awake.

If you're stirred from the deepest stages of slow-wave sleep, "you might have no idea where or who you are," Duffy says. In that case, it might help to snooze some minutes more. That way you can reawaken from a different stage of sleep, such as REM, when your body is closest to its wakeful state. "It might make things better," says Duffy. But if you're in REM already, snoozing could send you deeper and make things worse.

Q: WHY IS CANDY CRUSH SO ADDICTIVE?

Short answer It's easy to learn and hard to master.

A:

Mobile game *Candy Crush* has generated billions of dollars (and perhaps as many hours of wasted time) since its release, in 2012. What's the secret of this procrastination juggernaut? "It's very easy to learn," says Jesper Juul, who has written a history of this simple and addictive genre of games, known as Match-3.

Candy Crush, like other Match-3 games, uses a grid of tiles in various colors and shapes. Players swap those tiles to make matching stripes of three (or more) tiles, which then vanish with a satisfying whoosh. But



Juul says it gets surprisingly hard, level by level, to clear each board of tiles. A group of computer scientists in Rome proved last year that the course a Match-3 game will take is exceedingly difficult to predict.

If the game were too hard, players would just give up, so Match-3 games lure users with lots of tiny victories.

You can't make a move without getting a match and clearing tiles, so every turn delivers a jolt of positive feedback. Another factor, says Juul, is the lack of time pressure, which allows users to play distractedly, on their own time.

Candy Crush is not the first game to cash in on these qualities. Match-3's first gained popularity in 2001, with the release of *Bejeweled*, which uses gems in place of candy. The makers probably got the idea from the simple Russian game *Shariki*, released in 1994. If you follow the lineage all the way back to the 1980s, you'll arrive at what Juul calls the "primordial" matching tile game: *Tetris*.

The addictiveness of Match-3 games might not be inherent to their design, though. It's likely more about trends. Juul points out that the genre's popularity fluctuates in tandem with complex games like *World of Warcraft*. "It's popular because it's popular," says Juul. "It becomes a cultural moment ... that would have been impossible to predict."

Doctor *Designed.* Audiologist *Tested.* FDA *Registered.*

Affordable *New* Digital Hearing Aid *Outperforms* Expensive Competitors Delivers *Crystal - Clear* Natural Sound

Reported by J. Page

Chicago: Board-certified physician Dr. S. Cherukuri has done it once again with his newest invention of a medical grade all digital Affordable hearing aid.

This new digital hearing aid is packed with all the features of \$3,000 competitors at a mere fraction of the cost. Now, most people with hearing loss are able to enjoy crystal clear natural sound — in a crowd, on the phone, in the wind — without suffering through “whistling” and annoying background noise.

After years of extensive research, Dr. Cherukuri has created a ***state-of-the-art*** digital hearing aid that's packed with the features of those expensive \$3,000 competitors — at a ***fraction of the price.***

New Digital Hearing Aid Outperforms Expensive Competitors

This sleek, lightweight, fully programmed hearing aid is the outgrowth of the digital revolution that is changing our world. While demand for “all things digital” caused most prices to plunge (consider DVD players and computers, which originally sold for thousands of dollars and today can be purchased at a fraction of that price), yet the cost of a digital medical hearing aid remains out of reach.

Dr. Cherukuri knew that many of his patients would benefit but couldn't afford the expense of these new digital hearing aids. Generally they are not covered by Medicare and most private health insurance policies.

The doctor evaluated all the high priced digital hearing aids on the market, broke them down to their base components, and then created his own affordable version — called the MDHearingAid *AIR* for its virtually invisible, lightweight appearance.

- ✓ Nearly *invisible*
- ✓ *Crystal-clear* natural sound
- ✓ No suffering with ‘*whistling*’ or background noise
- ✓ *Outperforms* \$3,000 models
- ✓ Amazing *low price*

Affordable Digital Technology

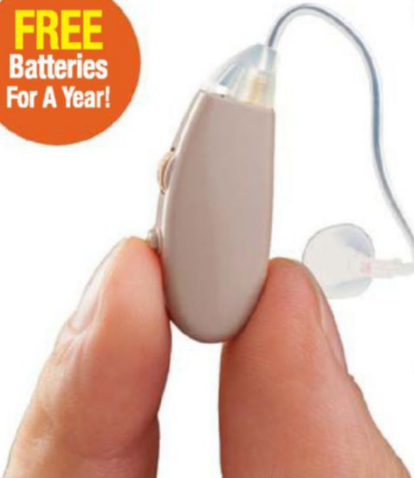
Using advanced digital technology, the MDHearingAid *AIR* automatically adjusts to your listening environment — prioritizing speech and de-emphasizing background noise. Experience all of the sounds you've been missing at a price you can afford. This doctor designed and approved hearing aid comes with a full year's supply of long-life batteries. It delivers crisp, clear sound all day long and the soft flexible ear buds are so comfortable you won't realize you're wearing them.

Try It Yourself At Home with a 45-Day Risk-Free Trial

Of course, hearing is believing and we invite you to try it for yourself with our RISK-FREE 45-Day home trial. If you are not completely satisfied, simply return it within that time period for a full refund of your purchase price.

MDHearingAid® *AIR*

**FREE
Batteries
For A Year!**



**Nearly
Invisible!**

Ecstatic Users Cheer

“It is very comfortable, light and almost invisible. I can't stop raving about it.”

— Laraine T.

“I'm a physician, and this product is just as effective as (if not more than) traditional overly-priced hearing aids. I will be recommending (it).”

— Dr. Chang

“As a retired advanced practice nurse, I purchased the MDHearingAid AIR after the Wall Street Journal review. I am so pleased with the quality. You are providing a real service to our affordable health care.”

— Ned R.

Compare to Expensive \$3000 Hearing Aids

- FDA-Registered Hearing Aid — not an imitation “sound amplifier”
- Nearly Invisible open-fit digital hearing aid
- Save Money — 90% less than traditional hearing aids
- 24/7 Physician/Audiologist Support
- FREE — Batteries, Color User Manual, Tubing and Domes, Cleaning Tool, and USA Shipping
- 45-Day in-home trial
- 100% Money-Back Guarantee

**For the Lowest Price plus
FREE Shipping Call Today**

800-873-0541

Use Offer Code CC47 to get
FREE Batteries for a Full Year!

www.MDHearingAid.com



45-DAY
RISK-FREE
TRIAL

Proudly Assembled in the USA
from Domestic & Imported Components.



ASK ANYTHING

JULY 2015

Q: DO COMPUTERS DIE OF OLD AGE?

Short answer Sadly, yes.

A:

Nothing lasts forever, not even electronics. "People assume electronic components will not age," says Bianca Schroeder, a computer scientist at the University of Toronto. Without moving parts, electronics seem unlikely to wear out. Yet even a standard memory module comprising little more than a capacitor and a transistor can begin to dodder. "It's kind of surprising, but most of the computer components I look at show signs of aging," Schroeder says.

Still, system-reliability experts know relatively little about components' life spans in the wild. "We don't have much data," Schroeder admits. "People usually don't run their computers long enough to find out if they die." Not to mention, manufacturers don't like to publish failure rates from their in-house product tests, and according to



Schroeder, "they have no knowledge of how these components behave in the field." Lab testing environments rarely match the physical jostling, temperature swings, and dust accumulation of the real world.

A few facts are known. In 2013, software engineer Brian Beach put out reliability stats for Backblaze, a data-storage company that runs 35,000 disk drives at all times. He found that about 5 percent of

the firm's disks fail in their first 18 months, most due to manufacturing flaws. Over the next year and a half, any surviving disks have a failure rate of 1.4 percent. And after three years of use, surviving disks fail at a rate of more than 11 percent annually.

Reliability experts call this the "bathtub curve" because of its inflated failure rates in infancy and again in old age. The curve applies only to hard disks' moving pieces, Schroeder says. But software too can grow old and incompetent. Web browsers "leak" memory over time, and frequently used file systems provide less-efficient access to a user's data.

Such aging might not lead to outright death—for example, a user might be able to "rejuvenate" a system by rebooting—but it could slow a computer to a crawl. "At some point," Schroeder says, "that's the same as being broken." 

Save
up to

50% or more on
heating costs*

envi[™]
wall-mounted room heater

economical. safe. simple.

- energy saving** heats room for as little as 4 cents per hour*
- ultra-safe** leave unattended 24/7; cool to the touch
- healthy** fanless - doesn't blow dust & allergens or dry the air
- effective** 100% Pure Stack Convection; gentle whole room warmth!
- silent** fanless design, auto dimming power light
- easy install** installs in minutes, no drill; hardwired & plug-in models
- stylish** slim space saving design, 19" wide x 22" high x 2" thin!

eheat.com 1-800-807-0107

(*visit website for details) | 10% OFF Coupon: PSS15 | 2 or more 15% OFF Coupon: PSS1515 | Free Shipping to USA & Canada*



FIX NASTY SCRAPES FOR LITTLE SCRATCH

See how easy it is to restore
that like-new finish in just an
afternoon. Watch our online
how-to videos to show you how.



Paint pens
½ oz and 2 oz bottles
12 oz spray cans
Ready-to-spray pints,
quarts and gallons

Automotivetouchup.com
888-710-5192



GovMint.com releases new American Silver Eagles at our LOWEST PRICE in years!

Millions of people collect the American Eagle Silver Dollar. In fact it's been the country's most popular Silver Dollar for over two decades. Try as they might, that makes it a very hard "secret" to keep quiet. And right now, many of those same people are lining up to secure the brand new 2015 U.S. Eagle Silver Dollars — placing their orders now to ensure that they get America's newest Silver Dollar — in stunning Brilliant Uncirculated condition — before millions of others beat them to it.

America's Brand New Silver Dollar

This is a strictly limited release of one of the most beautiful silver coins in the world. Today you have the opportunity to secure these massive, hefty one full Troy ounce U.S. Silver Dollars in Brilliant Uncirculated condition. The nearly 100-year-old design features walking Lady Liberty draped in a U.S. flag, while the other side depicts a majestic U.S. Eagle, thirteen stars, and an American shield.

But the clock is ticking...

The Most Affordable Precious Metal

Silver is by far the most affordable of all precious metals — and each full Troy ounce American Eagle Silver Dollar is **government guaranteed** for its 99.9% purity, authenticity, and legal tender status.

Our Lowest Price in Years

Why are we releasing the most popular Silver Dollar in America at our lowest introductory price in years? To introduce you to what hundreds of thousands of smart collectors and satisfied customers

have known since 1984 — GovMint.com is *the best source for coins worldwide.*

Timing is Everything

Our advice? Keep this to yourself. The more people who know about this offer, the worse for you. Demand for Silver Eagles in recent years has shattered records. Experts predict that 2015 Silver Eagles may break them once again. Our supplies are limited and there is a strict limit of 50 per household.

30-Day Satisfaction Guarantee

You must be 100% satisfied with your 2015 American Eagle Silver Dollars or return them within 30 days of receipt for a prompt refund (*less s/h*). Don't miss out on this exciting new release. Call immediately to secure these American Eagle Silver Dollars NOW!

**2015 American Eagle
Silver Dollar BU..... \$19.95 ea.**

Introductory Price \$17.95 ea.
(*plus s/h*) (LIMIT 10)

*Additional 2015 Silver Eagle BU
Dollars may be purchased for \$19.95
each (plus s/h). Limited to 50 total coins
per household.*

For fastest service, call today toll-free

1-800-956-7267



GOVMINT.COM®

GovMint.com • 14101 Southcross Dr. W. Dept. PEG349-06 • Burnsville, Minnesota 55337

Prices and availability subject to change without notice. Past performance is not a predictor of future performance. NOTE: GovMint.com® is a private distributor of worldwide government coin and currency issues and privately issued licensed collectibles and is not affiliated with the United States government. Facts and figures deemed accurate as of March 2015. ©2015 GovMint.com.

THE BEST SOURCE FOR COINS WORLDWIDE™



Dr. Winnifred Cutler Creator of 10X

BIOLOGIST'S AFTERSHAVE ADDITIVE INCREASES AFFECTION from WOMEN



ATHENA PHEROMONE 10X

Dirk (FL) "I earned my PhD in physics and taught college for 27 years. After I retired from University life I decided to take a job teaching physics in the local high school. Academics has always been exciting for me. Anyway, about the 10X. The interesting thing is that, just after I began using it at the school—which had 36 women teachers—I was called into the principal's office.

She said, "You are affecting the women teachers. There is something about you that affects them. Can you tone it down?" It also did not hurt the attention my wife gave me. She has sort of become ravenous. Normally, I am not attacked in trains and elevators, but she has been AT me and I am enjoying it enormously. Thanks!"

PROVEN EFFECTIVE IN 3 DOUBLE BLIND STUDIES

Created by Winnifred Cutler, Ph.D. in biology from U. of Penn, post-doc at Stanford. Co-discovered human pheromones in 1986 (Time 12/1/86; and Newsweek 1/12/87).

athenainstitute.com

Athena 10X is designed to **enhance attractiveness**. Vial of 1/6 oz. added to 2-3 oz. of your cologne or aftershave **lasts 4 to 6 months, or use straight**. Contains **synthesized human attractant pheromones**.

Effective for 74% in 8 week published scientific study. Not guaranteed to work for all, since body chemistries differ, but **will work for most**. Cosmetics not aphrodisiacs.

Not in stores. Call (610) 827-2200 - Order online or send to: Athena Institute, Dept PS, 1211 Braefield Rd. Chester Springs, PA 19425
FREE US SHIPPING

Please send me _____ vials of 10X for men @\$99.50 and/or _____ vials of 10:13 for women @\$98.50 for a *total _____ by: ☐ money order ☐ check

☐ Visa/M/C/Disc.

Exp _____ CVV _____ Sig _____

to: Name _____

Address _____

City/State _____ zip _____

Phone: _____ email _____

(*PA add 6% tax, Canada add US \$10.00 per vial) PS

Get a **FREE Info Kit and DVD** plus savings up to \$75...



Blocks the sun **before** it can enter and heat your home.

In Solar-Powered, Motorized, and Manual models

SunSetter EasyShade®

By the makers of SunSetter Awnings, 184 Charles Street, Malden, MA 02148

EasyShades: A Better Way to Shade Your Home...

EasyShades keep your home cooler and help lower air conditioning bills. They provide daytime privacy, shade, and breeze protection. They block 90% of sun, wind, and mist yet let in filtered light and air, without taking up interior space.

Get a FREE Info Kit & DVD

Plus a Savings Certificate worth up to \$75! Call:

Toll Free: 1-800-257-6613 Ext. 109
or go to www.easysshade.com

WhiteWalls® Magnetic Whiteboard Steel Walls

WhiteWalls® give you and your team an unlimited blank slate that encourages original ideas and fosters out of the box solutions.

WhiteWalls.com



Dive Bar T-shirts

DIVE BAR SHIRT CLUB

Join the Club!
You'll get a new T-shirt every month from the best bars you've never heard of!

DiveBarShirtClub.com

Weed Razer

Tools for controlling aquatic vegetation

The most efficient and effective tool made for removing submerged weeds.

Clears Your Lake or Pond Weeds in Minutes

Clears a path 48" wide—returns weed free!

Using the Weed Razer is simple:

1. Give it a toss
2. Let it sink
3. Pull it in
4. Repeat



Visit our website to see our Algae control and other pond products!

Toll Free: 877-356-6455

www.WeedRazers.com

YOUR PAINT'S WORST ENEMY HAS MET IT'S MATCH...

SQUIRT
SQUIRT OUT A FEW DROPS OF THE OEM-MATCHED PAINT

SQUEEGEE
USING THE SPECIAL SQUEEGEE, SMEAR THE PAINT INTO THE CHIPS

BLEND
SEALACT BLENDS THE EXCESS PAINT

PERMANENT REPAIRS IN JUST MINUTES, NOT HOURS!

SQUIRT N SQUEEGEE KIT IS THE FAST, SIMPLE, DRAMATIC WAY TO REPAIR PAINT CHIPS - WITH NO PAINT BLOBS!

ORDER YOUR KIT TODAY -
REPAIR KITS AVAILABLE IN 4 SIZES FROM \$39.95

RATED #1 BY THE WALL STREET JOURNAL

DR.COLORCHIP
AUTOMOTIVE PAINT CHIP REPAIR SYSTEMS
DrColorChip.com • 866.372.2548

THE DR® TRIMMER/MOWER Just Got BETTER!



NEW LOW PRICE!

- Trims, mows waist-high grass and weeds.
- Cuts brush, saplings up to 3" thick with exclusive accessories.
- Thickest, longest-lasting cord available anywhere (225 mil Sawtooth™).

88007X © 2015

FREE SHIPPING 6 MONTH TRIAL

Call for FREE DVD and Catalog!

TOLL FREE **800-487-1379**
DRtrimmers.com



America's #1 Selling Brush Mower for Over 25 Years!

DR® FIELD and BRUSH MOWERS

- The power to mow down saplings up to 3" thick.
- 4-Season use with quick change attachments.



88008X © 2015

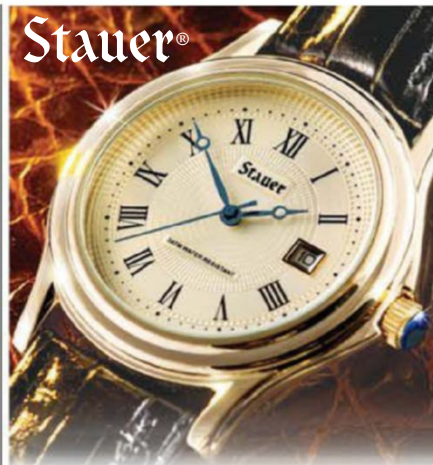
FREE SHIPPING 0% 36 MO. FINANCING

Call for FREE DVD and Catalog!

TOLL FREE **800-487-1379**
DRfieldbrush.com



Stauer®



Back Again for the First Time

*Our modern take on a 1929 classic, yours for the unbelievably nostalgic price of **ONLY \$29!***

Stauer Metropolitan Timepiece ~~\$199~~

Offer Code Price **\$29** + S&P **Save \$170**

1-888-870-9149

Your Offer Code: **MTW367-02**

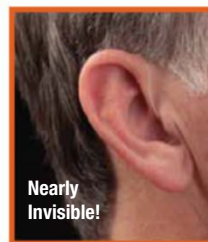
You must use the offer code to get our special price.

Luxurious gold-finished case with sapphire-colored crown
Crocodile-embossed leather strap fits wrists 6 1/4"-8 3/4"
Water-resistant to 3 ATM

14101 Southcross Drive W., Dept. MTW367-02
Burnsville, Minnesota 55337 www.stauer.com

TINY NEW AFFORDABLE HEARING AID

The **MDHearingAid® AIR** is doctor designed and delivers the same hearing experience as devices costing thousands for 90% less. This FDA-Registered state-of-the-art digital hearing aid provides crystal clear, natural sound — in a crowd, on the phone, in the wind — without "whistling" or annoying background noise. **Call today for a 45-Day, Risk-Free Trial with a 100% Money Back Guarantee and get FREE batteries for a full year.**



Nearly Invisible!

ONLY YOU CAN PREVENT WILDFIRES.
www.smokeybear.com

BE CAREFUL.

Ad

RotoCube® Rotating Whiteboard Bulletin Tower



Share information where people gather.

No Wall Needed. Up to 30 panel styles

RotoCube.com

800 624 4154

Call 1.800.873.0541

with promo code CD14 or visit

MDHearingAid.com

Take a Bite!



Adult Products & Novelties

Adam & Eve
adamandeve.com

Also valid at participating Adam & Eve stores.
Certain items not available for discount.

MATHTUTORDVD
Press Play For Success

Having Math Problems?

Yes

No

Earn A's with Ease

Get Help Now!

Basic Math
Pre-Algebra
Algebra thru Calculus
Differential Equations
Physics
Chemistry
Probability/Statistics
Calculator Tutorials

*Begin Learning
in Minutes!*
MathTutorDVD.com

- ✓ Raise grades or your money back
 - ✓ Award Winning Courses
 - ✓ Money Back Guarantee
- Order By Phone: 877-MATH-DVD

View all courses online or order DVDs at:

MathTutorDVD.com

5-Minute Fence Stain



- Stain 100 ft of fence in just 5 minutes!
- Sprayer attaches directly to garden hose.
- No masking, simply hose off over-spray.
- One quart covers 600 square ft.
- Select from three natural wood tones; Natural Cedar, Dark Cedar or Redwood.

FiveMinuteFence.com

FREE Report \$1500 Value

Scams Exposed

Learn the truth about distilled, mineral, spring, filtered, bottled, well, tap, alkalized, reverse osmosis & more...

Call or visit
waterscamsexposed.com

800-874-9028 Ext 781

PO Box 494000 Leesburg FL 34749-4000

ADVERTISE!

Your Product or Business in
Popular Science

Showcase & Classified today!



Shawn Lindeman @ 212-779-5501

Chip Parham @ 212-779-5492

Frank McCaffrey @ 212-779-5510



www.popsci.com

HELLO DESIGN, MEET SEXY.



THE ESSE CHAISE

Beds are for sleeping. The Esse Chaise is for everything else. Discover what your sex life has been missing at

liberator.com

LIBERATOR
BEDROOM ADVENTURE GEAR

www.motionmodels.com
THE WORLDS FINEST READYMADE AND CUSTOM TRUE MUSEUM QUALITY AIRPLANE AND NAVY AND COAST GUARD SHIP MODELS




WE CAN CUSTOM MAKE MOST COAST GUARD SHIPS AND PLANES
USCGC CHASE
WHEC 718
PICTURED



WE CAN CUSTOM MAKE MOST NAVY SHIPS AND PLANES

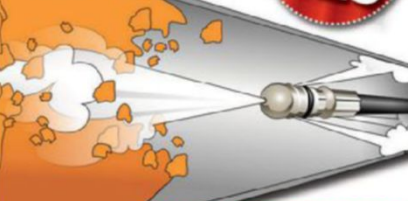


CVN-77 THE USS
GEORGE H.W. BUSH
MADE FOR PRESIDENT BUSH

www.motionmodels.com
1-800-866-3172

UNCLOG DRAINS
with your
Pressure Washer

100 Ft. Sewer Jetter
ONLY \$129



\$10 OFF
GIFT CODE: **PS44** LIMITED TIME

Made in the USA

ClogHog.com 877.992.5644

GOLD/JEWELRY

THE NINE PLANETS RING
HANDCRAFTED WITH AN ORBITING
GIBBON METEORITE BAND
IN 18K GOLD SET WITH 9 GEMSTONES



JEWELRYDESIGNSFORMEN.COM
831.336.1020

HEALTH & FITNESS

GOT WARTS?
Electronic Wart Remover
100% successful home treatment
(800) 645-0234
www.wartabater.com

**NAME BRAND HEARING AIDS
60% SAVINGS**

- All Makes & Models • Free Catalog
- Ranging from Analog to Ultimate Digital
- 45 Day Home Trial • 50 Yrs Experience

LLOYD HEARING AID
1-800-323-4212 www.lloydhearingaid.com

POND & LAKE MANAGEMENT

LAKE OR POND? Aeration is your 1st step toward improved water quality. Complete Systems \$169 - \$369. Waterfall? - 11,000gph Water Pump only 3.6 amps! 2yr warranty! Just \$399.95 www.fishpondaerator.com 608-254-2735 ext. #3

Pre-Assembled - Installs in Minutes!

CasCade 5000
Floating POND FOUNTAIN!
Aerator
Now Available Factory Direct!
MSRP (\$1100) You Pay \$698.95!
Complete with light & timer,
100 ft power cord, 1yr warranty!
(Also available in 3/4hp & 1.25hp)
Call 7days/week! **FAST UPS shipping right to your door!**
(608) 254-2735 **www.fishpondaerator.com**

Elegance & Improved Water Quality

WATER PURIFICATION

BEST DRINKING H2O!

Doppler Ultra Sound tests at any Hospital PROVES it!

FREE Bottled Water SAMPLE!
570.296.0214

WATER REPORT SCAM! - One of 5 companies cited by The Consumer Product Safety Commission! American Cancer Society founder at my home 50 yrs ago: "Help the American people by recycling water 100's of times/gallon (NOT once!) to destroy deadly viruses that also travel with steam and survive boiling!" 13 Patents, 332 FDA Tests, at 85 this works!

VIDEO PROOF:
This increase in ENERGY CAN CHANGE YOUR LIFE! **800 433-9553**

johnellis.com/RonaldReaganStory

POPULAR SCIENCE DIRECT



*****ERROR*****



DONT LET PHOTO TICKETS DRAIN YOUR WALLET

License plate cover that prevents photo tickets!

- 100% Effective
- No-Ticket Guarantee
- Easy 30 Second Install
- Works against all speed & red light photo cameras!

www.PhotoMaskCover.com
(877) 992-9688

SPECIAL OFFER!

Purchase your PhotoMaskCover today and use discount code **SCI5** for a 5% discount.

Order now to take advantage of our limited time **FREE** shipping this month!

FREE

All you need to know about the Bible for Salvation.
<http://abouts Salvation.blogspot.com/>
Free CD, About Salvation.
P.O. Box 156 Wartburg, TN 37887-0156

PARTS EXPRESS
YOUR ELECTRONICS CONNECTION



FREE CATALOG
Over 18,000 audio/video products

For more information and a special offer visit:
parts-express.com/pop
1-800-338-0531

A UNIVERSAL LIFT FRAME



Why spend a fortune for a lift chair?
Enhansit simply attaches to the bottom of your favorite recliner in minutes, making your favorite, comfortable recliner a Lift Chair quickly and easily.

Easy as 1-2-3
Check Website for Specials! **www.enhansit.com**
1-888-217-1211

Popular Science reserves the right to refuse any advertising order. Only publication of an advertisement shall constitute final acceptance of an order. Publication does not constitute an agreement for continued publication. All orders are subject to the applicable rate card, copies of which are available upon request sent to the address provided. Popular Science, 2 Park Avenue, New York, NY 10016

GAMES, TOYS & MODELS

STEAM MODELS!
Over 150 Working Steam Toys, Stationary Engines, Tractors, Trains, Trucks, Accessories & Stirling Hot Air Engines!
STEAM CATALOG \$6.95
YESTERYEAR TOYS & BOOKS INC.
BOX 537 • DEPT. PS • ALEXANDRIA BAY, NY 13607
1-800-481-1353 • www.yesteryearthoys.com



OF INTEREST TO MEN

WHERE SINGLES MEET
Browse Ads & Reply Free!
1-888-634-2628
Use FREE Code 3185, 18+

From the Archives

FIGHTER PLANES DEFEND THE HOME FRONT

↓

In early 1941, the United States had yet to enter into World War II, but weapons and warplanes were already a topic of national interest. One of those planes was the F4F-3 Wildcat, which the Naval Air Force deployed to monitor the coasts. The fighter, which graced the February 1941 cover of *Popular Science*, could drop 100-pound bombs while flying at speeds greater than 250 mph. As we wrote then, "Perhaps our patrol bombers and flying fortresses can't send capital ships with heavy deck armor to the bottom, but they can certainly send them to dry dock, back where they came from." Aviation technology has advanced significantly in the 70 years since World War II, and it stands to change even more. Future air battles will likely be fought by unmanned craft carrying much heavier artillery. To read about the weaponry, airborne and otherwise, being developed for new global conflicts, turn to page 46.

RACHEL FOBAR

7,885

Number of F4F-3 Wildcats built



AERIAL FACE-OFF

F4F-3 (retired 1945)**Top Speed** 328 mph**Top Altitude** 37,500 feet**Weapons** Four .50-inch machine guns and two 100-pound bombs**Weight** 8,152 lb.**Cost Per Plane** \$30,000**F-35A CTOL** (in development)**Top Speed** 1,200 mph**Top Altitude** 50,000 feet**Weapons** 18,000 lb. total payload, including laser- and GPS-guided bombs and air-to-air missiles**Weight** 70,000 lb.**Cost Per Plane** \$108 million

POPULAR SCIENCE magazine, Vol. 287, No. 1 (ISSN 161-7370, USPS 577-250), is published monthly by Bonnier Corp., 2 Park Ave., New York, NY 10016. Copyright ©2015 by Bonnier Corp. All rights reserved. Reprinting in whole or part is forbidden except by permission of Bonnier Corp. Mailing Lists: We make a portion of our mailing list available to reputable firms. If you would prefer that we not include your name, please write to POPULAR SCIENCE, P.O. Box 6384, Harlan, IA 51593-1864. POSTMASTER: Send address changes to POPULAR SCIENCE, P.O. Box 6384, Harlan, IA 51593-1864. Periodicals postage paid at New York, NY, and additional mailing offices. Subscription Rates: \$19.95 for 1 year. Please add \$10 per year for Canadian addresses and \$20 per year for all other international addresses. Canada Post Publications agreement #40612608. Canada Return Mail: IMEX Global Solutions, P.O. Box 25542, London, ON N6C 6B2. Printed in the USA. Subscriptions processed electronically. Subscribers: If the post office alerts us that your magazine is undeliverable, we have no further obligation unless we receive a corrected address within two years. Photocopy Permission: Permission is granted by POPULAR SCIENCE® for libraries and others registered with the Copyright Clearance Center (CCC) to photocopy articles in this issue for the flat fee of \$1 per copy of each article or any part of an article. Send correspondence and payment to CCC (21 Congress St., Salem, MA 01970); specify CCC code 0161-7370/85/\$1.00-0.00. Copying done for other than personal or reference use without the written permission of POPULAR SCIENCE® is prohibited. Address requests for permission on bulk orders to POPULAR SCIENCE, 2 Park Ave., New York, NY 10016 for foreign requests. Editorial Offices: Address contributions to POPULAR SCIENCE, Editorial Dept., 2 Park Ave., New York, NY 10016. We are not responsible for loss of unsolicited materials; they will not be returned unless accompanied by return postage. Microfilm editions are available from Xerox University Microfilms Serials Bid Coordinator, 300 N. Zeeb Rd., Ann Arbor, MI 48106.

Listed coverages are provided based on whether Comprehensive and Collision Coverages are purchased. Details of coverages or limits may vary by state. All coverages are subject to the terms, provisions, exclusions and conditions in the policy and any endorsements. State Farm Mutual Automobile Insurance Company • State Farm Indemnity Company • Bloomington, IL



Choose coverage from the road captain. Our new, affordable rates include coverage that other companies charge as extras. Things like: help repairing or replacing your protective gear, costs incurred from being stranded, emergency roadside assistance, and the got-your-back service of a State Farm® agent.



Call us today at 844.242.2554 or visit st8.fm/motorcycle

THE NEWEST THING IN BATTERIES ISN'T 100% NEW.

Introducing *Energizer*® EcoAdvanced™



Our longest-lasting alkaline is also the
WORLD'S FIRST AA battery made with **4% RECYCLED BATTERIES**.

that's positivenergy™

energizer.com/ecoadvanced

